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# Soil Report

## Sheep Project

**La Grande, Wallowa-Whitman National Forest**
**Union County, Oregon**



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# INTRODUCTION

The long-term sustainability of forest ecosystems depends on the productivity and hydrologic functioning of soils. Ground-disturbing management activities directly affect soil properties, which may adversely change the natural capability of soils and their potential responses to use and management. Forest soils are considered to be a non-renewable resource, as measured by human life spans, and maintenance or enhancement of soil productivity is an integral part of National Forest Management. The following section documents the soil resource effects of the proposed Sheep Creek Project. Specific management indicators to be analyzed include soil productivity, erosion potential, and soil stability. The report will analyze soil types within activity areas, their limitations, and offer methods that may allow for mitigation of limiting characteristics for a given soil or activity area.

Forest Service Manual 2520 Region 6 Supplement 2520-98-1 provides direction for the management of soils within activity areas in order to meet direction in the National Forest Management Act of 1976 and other legal mandates (Appendix A). NFMA directs the Forest Service to manage National Forest System lands under ecosystem management principles, without permanent impairment of land productivity and to maintain or improve soil and water quality. The R6 soil quality standards set thresholds beyond which soil quality is considered to be adversely impacted. A minimum of 80% of an activity area must be left in an acceptable soil quality condition.

This analysis utilizes the best available soil survey mapping for the Wallowa-Whitman National Forest (NF). It is important to note that soil surveys are constantly evolving and changing, as is science. Landtype associations (LTAs) were also used in this analysis, and are based on vegetation zones, geology groups, and landforms (USDA Forest Service, 2006). The general use for LTA data is forest or area-wide planning and watershed analysis, appropriate for the scale of this project.

A suite of Best Management Practices (BMPs) and Project Design Criteria (PDC) will be integrated into the design of alternatives and the analysis of effects to ensure that relevant natural resources are managed and protected in a manner consistent with policy, law, and regulation. BMPs and PDCs will also serve to ensure that implementation of the actions described in the Decision Notice are properly executed.

# RELEVANT LAWS, REGULATIONS, AND POLICY

## REGULATORY FRAMEWORK

### Land and Resource Management Plan

The Wallowa-Whitman National Forest Land and Resource Management Plan (LRMP) provides standards and guidelines for the soil resource (Wallowa-Whitman LRMP 4-21).

Goal: To maintain or enhance soil productivity

Standards and Guidelines:

- Conflicts with Other Uses. Give maintenance of soil productivity and stability priority over uses described or implied in all other management direction, standards, or guidelines. Exceptions may occur for such things as campgrounds or transportation facilities when it is determined, through environmental analysis, to be in the public interest.

- Protection. Minimize detrimental soil conditions with total acreage detrimentally impacted not to exceed 20 percent of the total acreage within the activity area including landings and system roads. Where detrimental conditions affect 20 percent or more of the activity area, restoration treatments will be considered. Detrimental soil conditions include compaction, puddling, displacement, and severe burning

- Give special consideration to scablands or other lands having shallow soils during project analysis. Such analysis will especially consider the fragile nature of the soils involved and, as necessary, provide protection and other mitigation measures.
- Use approved skid trails, logging over snow or frozen ground, or some equivalent system for limiting the impact and areal extent of skid trails and landings and to prevent cumulative increases from multiple entries in tractor logging areas.
- Re-establish vegetation following wildfire or management activities where necessary to prevent excessive erosion.

## Federal Law

### Organic Administration Act of 1897 (16 USC 473-475)

The Organic Administration Act of 1897 authorizes the Secretary of Agriculture to establish regulations to govern the occupancy and use of National Forests "…to improve and protect the forest within the boundaries, or for the purposed of securing favorable conditions of water flows, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States."

### Bankhead Jones Farm Tenant Act of 1937

The Bankhead-Jones Farm Tenant Act of 1937 authorizes and directs a program of land conservation and land utilization, in order to correct maladjustments in land use, and thus assist in controlling soil erosion, preserving natural resources, mitigating floods, conserving surface and subsurface moisture, protecting the watershed of navigable streams, and protecting the public lands, health, safety, and welfare.

### Knutson-Vandenberg Act of 1930

In addition, NFMA amends section 18 of Knutson-Vandenberg Act (KV). This amendment authorizes the use of KV funds to protect and improve the future productivity of the renewable resources of the National Forests, including soil and water. This project will prioritize KV funds for rehabilitation of non-system historic road templates that still exist on the landscape.

### Multi-Use and Sustained Yield Act of 1960

The project, with described mitigation and BMPs in place, would meet the intent and direction of the Multi-Use Sustained Yield Act of 1960. Sustained yield means achieving and maintaining into perpetuity a high-level annual or regular periodic output of renewable resources without impairment of the productivity of the land.

### National Forest Management Act of 1976 (NFMA) 16 USC 1604(g)(3)(i)

This project complies with NFMA 16 USC 1604 (g)(3)(i), which requires that project activities do not produce substantial and permanent impairment of the productivity of the land. Additionally, NFMA requires that timber will be harvested from National Forest System lands only where soil, slope or other watershed conditions will not be irreversibly damaged.

### 36 CFR 219.20

The project complies with 36 CFR 219.20, which requires conservation and protection of soil and water resources.

## Other Guidance or Recommendations

### Pacific Northwest (R6) Supplement 2500-98-1 (Regional Soil Quality Standards)

The Region 6 Soil Quality Standards found in FSM 2500 Supplement 2500-98-1 (USDA Forest Service, 1998), provide soil quality standards to assure the statutory requirements of NFMS Section 6(g)(3)(i) are satisfied. These soil quality standards protect the “productivity of the land” by setting limits for the degree of detrimental soil conditions. The R6 supplement specifies that at least 80% of an activity area (defined as land area affected by a management activity, including landings and system roads) have soil that is in an acceptable soil quality condition. In other words, detrimental impacts (including past management impacts) shall be less than 20% of an activity area. In areas where less than 20% detrimental soil conditions exist from prior activities, the cumulative detrimental effect of the current activity following project implementation and restoration must not exceed 20%. In areas where more than 20% detrimental soil conditions exist from prior activities, the cumulative detrimental effects from project implementation and restoration must, at a minimum, not exceed the conditions prior to the planned activity and should move toward a net improvement in soil quality.

## METHODOLOGY

## RESOURCE INDICATORS AND MEASURES

**Table 1. Resource indicators and measures for assessing soil effects**

| Attribute | Indicator | Measure | Used to address: P/N, or key issue? | Source (LRMP S/G; law or policy, BMPs, etc.)? |
|---|---|---|---|---|
| Productivity | Detrimental Soil Conditions | Acres previously harvested areas proposed for treatment | No | LRMP, FSM, NFMA, Multi-Use Sustained Yield Act |
| | | Acres of detrimental soil conditions | | |
| | Droughty Soils | Acres of droughty soil types proposed for treatment | | |
| | Sensitive Soils | Acres of sensitive soil types proposed for treatment | | |
| Erosion | Erosion Potential | Tons/year of hillslope erosion modeled from WEPP | | |
| | | Acres of proposed treatment activities on soils with high erosion potential | | |
| | | Miles of temporary roads on soils with high erosion potential | | |
| Slope Stability | Landslide Potential | Acres of proposed treatment activities on landslide prone areas | | |
| | | Miles of temporary roads on landslide prone areas | | |

## Soil Productivity

1. Acres of previously harvested areas proposed for treatment
2. Acres of detrimental soil conditions

3. Acres of droughty soil types proposed for treatment
4. Acres of sensitive soil types proposed for treatment

Soil productivity is a key factor to maintaining ecosystem function (Powers et al., 1998). Soil productivity is defined as the ability of the soil to supply the water and nutrients needed to sustain plant growth. Variables that influence soil productivity include physical soil characteristics, organic matter and soil biological activity. Past management activities in the analysis areas likely have caused Detrimental Soil Conditions (DSC) and impacted soil productivity. According to Region 6 Soil Quality Standards, detrimental soil conditions (e.g., compaction, displacement, puddling, severe burning, and erosion) from management activities should not exceed 20% of an Activity Area, including landings and system roads. Soil quality guidelines also include retention of soil organic matter, coarse woody material, and maintenance and protection of soil moisture regimes. Soil disturbance effects on productivity are dependent on the degree, extent, distribution, and duration of the effects (Clayton et al., 1987; Craigg and Howes, 2007; Froehlich, 1976; Snider and Miller, 1985). The degree and duration of soil disturbance effects are largely determined by inherent soil properties, such as texture, coarse-fragment content, or organic matter content. Extent, distribution, and, in some instances, degree of soil disturbance can be controlled by management constraints, such as changing the season of operation, spacing of skid roads, and the number of equipment passes (Page-Dumroese et al., 2009).

Many dry forest landscapes in the Blue Mountains can be found on soils unable to sustainably support current vegetation densities based on soil properties. Forested conditions on these droughty soils make stands susceptible to increased insect infestation, disease, and wildfire due to drought conditions. Reducing unsustainable vegetation densities will increase soil productivity by increasing available water and nutrients needed to sustain plant growth.

### Physical Soil Characteristics

Physical soil characteristics include soil depth, porosity and bulk density. Changes in these occur most often when ground-based equipment makes repeated passes over the soil (Lull, 1959). These activities compact soils and if soils are moist enough, cause rutting and puddling. All these changes to the physical soil characteristics reduce the pore space volume and water holding capacity. These physical changes reduce infiltration rates, slow soil drainage, impede root growth and reduce plant-available water and nutrients. Physical soil disturbances also decrease gas exchange, affecting both plants and soil biota. Some physical changes to soil characteristics are classified as detrimental soil conditions (DSC), which are often found in higher impacted areas. Regional soil quality standards define the thresholds beyond which soil quality is adversely impacted (See methodology section below).

### Organic Matter

Organic matter in its various forms is critical for long-term site productivity and ecosystem sustainability. Regional direction states it should be maintained in amounts sufficient to prevent short or long-term nutrient and carbon cycle deficits and to avoid detrimental physical and biological soil conditions. Organic matter is particularly important for water retention, cation exchange, nutrient cycling, and erosion control (Powers et al., 2005). Humus is decomposed organic matter. Duff and litter are partially decomposed leaves, needles and twigs less than three inches in diameter on the soil surface. In most coniferous trees, 85 to 90 percent of the total nutrients are contained in branches, twigs and foliage (Garrison et al., 1998). Coarse woody debris consists of woody stems greater than three inches in diameter and is essential to maintaining soil productivity (Harvey et al., 1994; Graham et al., 1994). This material has no effect on soil nitrogen or other nutrients regardless of decay stage and it can compete with vegetation for limited nutrients through immobilization (Busse, 1994; Prescott et al., 2002). Studies of post-harvest and site preparation activities showed that loss of organic matter can reduce soil productivity by changing soil physical, chemical and biological properties (Perry et al., 1989; Powers et al., 1990; Dyck et al., 1994; Everett et al., 1994; Harvey et al., 1994; Henderson, 1995; Jurgensen et al., 1997).

### Soil Biological Activity

Soil organisms, including fungi and bacteria, drive the nutrient cycling process by decomposing organic matter and mineralizing nutrients for use by plants. Soil organisms depend on organic matter for the nutrients they need to carry out their life processes. Decomposed large woody debris provides habitat for the survival of mycorrhizae fungi. These fungi form a symbiotic relationship with tree roots, increasing water and nutrient uptake by the trees and the fungi (Borchers and Perry, 1990).

## Soil Erosion

1. Tons/year of hillslope erosion modeled from WEPP
2. Acres of proposed treatment activities on soils with high erosion potential
3. Miles of temporary roads on soils with high erosion potential

Surface erosion is defined as the detachment and transport of soil particles by running water, waves, currents, moving ice, wind, or gravity. The main types of surface erosion are sheet, rill, and gully erosion (Brady and Weil, 2007). In sheet erosion, soil is removed more or less uniformly from the ground surface by raindrop splash. As this overland flow is concentrated, small channels develop (rills), and rill erosion occurs. Gully erosion results when the volume of water is further concentrated. The force of water cuts deeper into the soil, enlarging rills into larger channels termed gullies. Surface erosion is most serious on bare, non-vegetated soils surfaces where sheet and rill erosion are responsible for most soil loss. Erosion is infrequent on undisturbed forest soils for two reasons:

a) Abundant organic matter provides a protective layer on the soil surface that reduces the impacts of raindrops and allows water to infiltrate; and

b) The surface soil below the organic layer is by nature porous, allowing water to infiltrate into and through the soil profile (Goldman et al., 1986).

Soil erosion can occur when the surface soil is compacted or when the loose surface soil and its protective layer of organic material are changed by management activities. Compaction, rutting and puddling reduce the movement of water into the soil and tend to channel and concentrate water. As a result, run off (overland flow) is increased and carries soil particles with it. If the forest floor is disturbed, then runoff and erosion rates can increase by several magnitudes. Disturbance can be natural, such as wildfire, or human-induced, such as harvesting or prescribed burning for ecosystem management. When organic matter is removed, soil pores can be plugged by impact from raindrops resulting in overland flow and increased rates of soil erosion. Soil erosion can result in loss of soil productivity due to surface soils moving downslope and thus removing the materials with the greatest ability to hold moisture and nutrients. According to Region 6 Soil Quality Standards, for planning or implementation monitoring to meet acceptable levels of soil loss and soil management objectives, the minimum percent effective ground cover following cessation of any soil-disturbing activities is found in Table 2.

**Table 2. Region 6 Soil Quality Standard for Minimum Percent Effective Ground Cover**

| Erosion Hazard Class | Minimum Effective Ground Cover | |
|---|---|---|
| | 1st Year | 2nd Year |
| **Low** | 20-30% | 30-40% |
| **Medium** | 30-45% | 40-60% |
| **High** | 45-60% | 60-75% |
| **Very High** | 60-90% | 75-90% |

Effective ground cover is defined as the basal area of perennial vegetation, plus litter and coarse fragments (greater than 2mm sizes), including tree crowns and shrubs that are in direct contact with the ground. Exceptions may occur where specific projects meet erosion control objectives without meeting the ground cover objectives stated above.

## Slope Stability

1. Acres of proposed treatment activities on landslide and landslide prone areas
2. Miles of temporary roads on landslide and landslide prone areas

Mass wasting is the downslope movement of large mass of unstable soil, rock, and other debris due primarily to the forces of gravity (Brady and Weil, 2007; Brooks et al., 1997). Mass wasting can be caused by man-made disturbances or natural events, such as wildfire followed by high-intensity precipitation. Some areas are prone to mass failures because of the nature of the bedrock geology or soil (Vallier, 1995). There are a wide variety of types of mass wasting events, but the ones of most concern are debris avalanches (including debris torrents and flows) and landslides. Other types of mass wasting events occur, but these two general categories account for the greatest impacts. Debris avalanches involve the rapid movement of soil, rock, and organic debris in stream channels or dissections because of saturated soils, high stream flows, or other upslope mass movements. If the material is primarily saturated soil, it may liquefy and move as a mudflow. Landslides occur with a sudden shear failure and downhill movement of soil and/or rock materials, usually under very wet conditions, as a result of over steepening and the reduction of internal friction.

Management activities can saturate a soil by channeling water and concentrating it onto a limited area, for example, below a road culvert or a rutted skid trail. All mass failures triggered by human causes are classified as DSC. These disturbances cause long-term changes in soil productivity that can last centuries.

# INFORMATION SOURCES

## Evaluation of Soil Productivity

The gridded Soil Survey Geographic (gSSURGO) Database was used to determine the types of soils present within the project area. The soil survey was field verified throughout the summer of 2019 and no changes were made to the survey. The soil survey classifications allow soils to be grouped to permit the largest number and the most precise predictions possible about responses to use and management (USDA Natural Resource Conservation Service, 2017). This system allows for monitoring results from one taxonomic unit to be related to other, similar taxonomic units. Soil survey data was used to identify droughty soil properties. The soil survey was also used to identify sensitive soils which include volcanic ash-capped soils, clayey soils, udic (moist) soils, hydric soils, low productivity soils, and shallow soils.

The Forest Service Activity Tracking System (FACTS) data was used to identify past timber harvest information to evaluate existing conditions. Past harvest history was used in conjunction with field observations during the summer of 2019 to evaluate existing detrimental soil conditions (DSCs). This provided an understanding of soil productivity within activity areas, and how past activities may have influenced the soil resource. Field soil surveys were conducted using the Forest Soil Disturbance Monitoring Protocol (FSDMP), and R6 Soil Quality Standard definitions to determine DSC. Detrimental soil conditions are defined as:

- Detrimental Compaction
  - Volcanic Ash/Pumice Soils (Soils with Andic Properties). An increase in soil bulk density of 20 percent, or more, over the undisturbed level.
  - Other Soils. An increase in soil bulk density of 15 percent, or more, over the undisturbed level, a macropore space reduction of 50 percent or more, and/or a reduction below 15 percent macro porosity.

  Assess changes in compaction by sampling bulk density, macro porosity, or penetration resistance in the zone in which change is relatively long term and that is the principal root development zone. This zone is commonly between 4 to 12 inches in depth.

- Detrimental Puddling. Detrimental puddling is when the depth of ruts or imprints is six inches or more. Soil deformation and loss of structure are observable and usually bulk density is increased.
- Detrimental Displacement. Detrimental displacement is the removal of more than 50 percent of the A horizon from an area greater than 100 square feet, which is at least 5 feet in width.
- Detrimental Burned Soil. Soils are considered to be detrimentally burned when the mineral soil surface has been significantly changed in color, oxidized to a reddish color, and the next one-half inch blackened from organic matter charring by heat conducted through the top layer. The detrimentally burned soil standard applies to an area greater than 100 square feet, which is at least five feet in width.
- Detrimental Surface Erosion. For effectiveness monitoring, detrimental erosion is visual evidence of surface loss in areas greater than 100 square feet, rills or gullies and/or water quality degradation from sediment or nutrient enrichment. (See FSM 2532)

  For planning or implementation monitoring to meet acceptable levels of soil loss and soil management objectives, the minimum percent effective ground cover following cessation of any soil-disturbing activity should be:

| | Minimum Effective Ground Cover | |
|---|---|---|
| **Erosion Hazard Class** | **1st Year** | **2nd Year** |
| **Low** | 20-30% | 30-40% |
| **Medium** | 30-45% | 40-60% |
| **High** | 45-60% | 60-75% |
| **Very High** | 60-90% | 75-90% |

  The above erosion hazard classes are from Soil Resource Inventories, ecological unit inventories, the Region 5 Erosion Hazard Rating System (R5-2500-14) and locally adapted standard erosion models and measurements.

- Detrimental Soil Mass Wasting. Detrimental mass wasting is visual evidence of landslides associated with land management activities and/or degrades water quality. (See FSM 2532)

> Plan activities to avoid acceleration of natural landslide rates. Make Level I, II, or III stability analyses as appropriate. (Ref. USDA FS EM-7170-13 Vol. 1-3)

Field FSDMP surveys were completed 8/12/2019 – 10/15/2019. It should be noted that estimated values for DSCs are not absolute and are best used to describe the existing soil condition. The calculation of the percentage of additional DSCs from a given activity is an estimate, since DSCs depend on a combination of factors such as existing ground cover, soil texture, timing of operations, equipment used, skill of the equipment operator, the amount of wood being removed, and sale administration. The DSC estimates of proposed activities also assume that BMPs will be implemented and that soil recovery occurs over time.

Predicted DSCs from proposed temporary road and non-system road prisms are calculated based on average clearing width. Temporary and non-system road prisms are part of the productive land base as defined by NFMA Section 4 through 7, and therefore, predictions of potential impacts on soil productivity are required. All temporary roads and non-system roads are estimated to average 12 feet in width of total disturbance resulting in 1.5 acres of DSC per mile. All associated impacts from temporary road construction and closure are assigned to the related harvest units.

For existing condition analysis, Activity Areas (i.e., a spatial boundary with the same proposed activities) were established, as defined in R6 Soil Quality Standards and Guidelines. In this report, activity areas in reference to unit numbers found in proposed action data.

## Soil Erosion Potential

The gSSURGO data and interpretations from the National Forestry Manual were used to evaluate erosion potential off-road and-off trail, as well as road and trail erosion potential (USDA NRCS, 2004). Potential erosion ratings were determined by combining the effects of slope, soil erodibility factor Kw (whole soil), and content of rock fragments. The K-factor quantifies the susceptibility of soil particles to detachment and movement by water including the effects of rainfall, runoff, and infiltration. Values of K range from 0.02 to 0.69, and the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

The off-road and off-trail erosion ratings assess and assume:

- Sheet and rill erosion from exposed soil surfaces caused by various silvicultural practices, grazing, fire, and firebreaks,
- Activities that disturb the site resulting in 50 to 75 % exposed mineral surface layer in the affected area,
- And the use of any equipment type or size.

Off-road and off-trail erosion ratings indicate the hazard or risk of soil loss from off-road and off-trail areas after disturbance activities that expose the soil surface. Soils with “severe” ratings are very likely to have erosion, control measures for vegetation re-establishment on bare areas and structural measures are advised on these soils. Soils with “very severe” ratings are expected to have significant erosion is expected, loss of soil productivity and off-site damages are likely, and control measures are costly and generally impractical on these soils.

The road and trail erosion ratings assess and assume:

- The forces that natural precipitation events have to dislodge and move soil materials on roads, trails, and firebreaks,

- Activities on roads and trails that result in bare ground, compaction, and reshaping of the soil surface
- Use of trucks, skidders, off-road vehicles, and other similar equipment,
- The impact on compacted, bare road, trail surface using the representative value for slope gradient,
- Roads and trails are generally linear, continuous, and narrow ranging up to 7.5 meters in width.

Soils with a “severe” rating are expected to have significant erosion, roads will require frequent maintenance, and costly erosion control measures will be needed.

The Water Erosion Prediction Project (WEPP) model was used to predict hillslope erosion for all alternatives. The WEPP erosion model is a process-based, continuous simulation erosion prediction model that simulates hillslope rill, interrill erosion processes, hydrologic and erosion processes on small watersheds. The model considers the spatial and temporary variability in topography, surface roughness, soil properties, and land use conditions on hillslopes. Data inputs to WEPP included:

- Observed GRIDMET with PRISM Revision climate method,
- Slope data from the US Geological Survey (USGS) Digital Elevation Model (DEM),
- SSURGO soil data,
- Landcover from USGS National Landcover dataset. The landcover was adjusted from untreated conditions to treated conditions using Disturbed WEPP provided ground cover assumptions.

The model was run once to calculate baseline hillslope erosion, and the model was run for each alternative to calculate hillslope erosion after proposed treatments. The model generates the mean annual average soil loss for each watershed modeled, which is averaged from the average of each hillslope within the watershed. Return Period Analysis is also generated, which provides probabilities of erosion rates in the first year following treatments given a range of precipitation scenarios, represented as precipitation return intervals (e.g., 2 tons of erosion if a 30-year precipitation event occurs during the first year following treatment).

### Slope Stability

The geology mapping used in this project was the Geology of the upper Grande Ronde River basin, published by Oregon Department of Geology and Mineral Industries (DOGAMI) in 2010. This mapping provided specific data on landslides and landslide prone areas. Mapped landslide and landslide prone areas will have field validation before implementation to ensure slope stabilization.

## SCIENTIFIC UNCERTAINTY AND CONTROVERSY

Site and soil productivity rely on complex chemical, physical, and climatic factors that interact within a biological framework. For any given site and soil, a change in a key soil variable (e.g., bulk density, soil loss, and nutrient availability) can lead to changes in potential soil productivity. Defining the threshold at which productivity is detrimentally disturbed is controversial. The rationale for the 15% limit of change in soil bulk density was largely based on the collective judgment of soil researchers, academics, and field practitioners, and the accepted inability to detect changes in productivity less than 15% using current monitoring methods (Powers, 1990). Note that volcanic ash and pumice soils, have a 20% limit of change in soil bulk density due to inherently low soil bulk density. Powers (1990) states that the soil quality guidelines are set to detect a decline in potential productivity of at least 15%. This statement does not mean that the Forest Service tolerates productivity declines at this level, but that it recognizes problems with detection limits.

Soil quality standards are being studied by a cooperative research project called the North American Long-Term Soil Productivity Study (LTSP). The 5- and 10-year results were recently published (Page-Dumroese et al., 2006; Fleming et al., 2006; Sanchez et al., 2006). The LTSP study is ongoing and provides the best available science to resource professionals. In a 10-year study, no observed reduction in tree growth occurred as a result of compaction or organic matter removal in plots with soils generally similar to those found in the project area (silt loam) (Powers et al. 2005). These results are relatively short-term and involve many site- and soil-specific factors. Future results from the ongoing study should be helpful for assessing harvest practices on soil productivity.

Additional controversy surrounds the use of the term “irreversible” in the NFMA. The NFMA has guidelines that “insure that timber will be harvested from NFS lands only where soil, slope, or other watershed conditions will not be irreversibly damaged.” The DSC described in this analysis does not necessarily result in substantial and permanent impairment. Detrimental soil conditions are reversible if the processes (organic matter accumulation, moisture, topsoil retention, and soil biota) are in place and if time is allowed for recovery. Loss of the volcanic ash cap could occur through erosion or removal by excavation for temporary roads and/or skid trails. Recovery from damage and/or loss of ash could still occur in the remaining subsurface and volcanic ash soils. Under Alternatives 2 and 3, loss of ash cap soils wouldn’t be substantial and would be mitigated through BMPs and PDCs to limit harvest activities to occur under dry or frozen conditions and to pull topsoil back over any disturbed surface to prevent permanent loss of productivity.

## SPATIAL AND TEMPORAL CONTEXT FOR EFFECTS ANALYSIS

The analysis area forms the boundary for the direct, indirect, and the cumulative effects in this soil analysis. It consists of the proposed actions within each analysis area. This analysis area was selected because it is where the effects of implementing the proposed activities would occur. The effects on soils would not extend beyond the analysis areas proposed for treatment. Natural and human-induced erosional processes may transport detached soil to a new location, if this occurs it is unknown if some portion of this material will end up outside of the project boundary.

The temporal boundaries for analyzing effects start from the initiation of historic forest activities, because soil disturbance can remain on the landscape for many decades. Short-term impacts are considered to be within 15 years and long-term effects being those that last for more than 15 years. Effects that are eliminated by the natural course of a single growing season are not considered effects because they are so short lived.

# AFFECTED ENVIRONMENT

**Table 3. Resource indicators and measures for the existing condition within the project area**

| Resource Element | Resource Indicator | Measure | Existing Condition |
|---|---|---|---|
| Soil Productivity | Detrimental Soil Conditions | Acres of previously harvested areas | 23,079 |
| | | Acres of detrimental soil conditions | 1,488 |
| | Droughty Soils | Acres of droughty soil types | 5,797 |
| | Sensitive Soils | Acres of sensitive soil types | 22,650 |
| Soil Erosion | Erosion Potential | Tons/year of hillslope erosion modeled from WEPP | 0.33 |
| | | Acres of soils with high erosion potential | 14,007 |
| | | Miles of temporary roads on high erosion potential soil | 0 |
| Slope Stability | Landslide Potential | Acres of landslide and landslide prone areas | 1,518 |
| | | Miles of temporary roads on landslide and landslide prone areas | 0 |

## SOIL PRODUCTIVITY

In order to determine the existing condition of soils within the proposed activity areas, field investigations were conducted to determine if and how existing soil condition was affected by past management activities or other dispersed activities (e.g., off-highway vehicle travel and firewood cutting). In addition, areas within proposed activity areas that would require Project Design Criteria (PDC) to address conditions, such as sensitive soils that are wet, steep, or had evidence of past harvest that caused compaction, displacement, rutting, puddling, or soil erosion, were identified.

Most soils on the Wallowa-Whitman NF, including those within the project area, have a surface that formed in or is strongly influenced by volcanic ash loess and, thus, are similarly classified. Since most soil quality monitoring on the Wallowa-Whitman NF has occurred on soils that have a volcanic ash-influenced surface, there are a large number of both quantitative and qualitative ratings that relate to the soils in the project area. This information has two valuable implications:

1. We can estimate the amount of detrimental soil disturbance that exists from past management activities by doing transects and observing the amount of visible detrimental disturbance present and

2. We can estimate the amount of detrimental soil disturbance to expect from proposed management activities on given soil types and thus estimate the effects on the soil resource.

### Detrimental Soil Conditions

Several vegetation management projects have been completed in portions of the project area over past decades. Multiple entries over many decades for timber harvest and other purposes have occurred, and residual soil disturbance is widespread in extent. Based on field visits and monitoring units, many of the soils are recovering with the assumption that they were impacted at various levels during previous entries. Past harvest activities that have project records are dated from 1960s to 2010s. Past harvest prescriptions include commercial thin, improvement cut, overstory removal cut, patch clearcut with and without leave trees, pre-commercial thin, salvage cut, sanitation cut, seed-tree seed cut, shelterwood establishment cut, and single-tree selection, and past harvests without project records. Before the current forest plan, skid trails were often not pre-designated, and as a result, were randomly distributed throughout the old units. Skid trails were spaced approximately 50 to 100 feet apart. Table 4 below, summarized DSC results for activity areas proposed in this project. Existing condition DSC calculations include known system and non-system roads, as directed by Region 6 Soil Quality Standards.

**Table 4. Existing Detrimental Soil Conditions**

| Unit | Acres | Existing Condition DSC (%) |
|---|---|---|
| 1 | 26 | 13% |
| 2 | 3 | 13% |
| 3 | 6 | 4% |
| 4 | 10 | 4% |
| 5 | 12 | 13% |
| 6 | 3 | 16% |
| 7 | 1 | 6% |
| 8 | 30 | 13% |
| 10 | 80 | 4% |
| 11 | 29 | 13% |
| 12 | 15 | 9% |
| 13 | 12 | 10% |
| 14 | 15 | 5% |
| 15 | 52 | 13% |
| 16 | 12 | 13% |
| 17 | 18 | 5% |
| 18 | 112 | 13% |
| 19 | 2 | 4% |
| 20 | 10 | 4% |
| 21 | 8 | 5% |
| 22 | 13 | 9% |
| 23 | 24 | 7% |
| 24 | 19 | 21% |
| 25 | 4 | 17% |
| 26 | 19 | 17% |
| 27 | 22 | 17% |
| 28 | 17 | 17% |
| 29 | 41 | 17% |
| 30 | 24 | 13% |
| 31 | 27 | 16% |
| 32 | 68 | 16% |
| 33 | 14 | 7% |
| 34 | 154 | 14% |
| 35 | 23 | 16% |
| 36 | 26 | 13% |
| 37 | 31 | 14% |
| 38 | 10 | 14% |
| 39 | 28 | 16% |
| 40 | 18 | 16% |
| 41 | 59 | 16% |
| 42 | 87 | 16% |
| 43 | 29 | 5% |
| 44 | 3 | 6% |
| 45 | 9 | 8% |
| 46 | 12 | 16% |
| 47 | 33 | 9% |
| 48 | 42 | 8% |
| 49 | 16 | 9% |
| 50 | 12 | 13% |
| 51 | 14 | 17% |
| 52 | 8 | 9% |
| 53 | 10 | 16% |
| 54 | 32 | 16% |
| 55 | 55 | 16% |
| 56 | 20 | 10% |
| 57 | 25 | 16% |
| 58 | 29 | 18% |
| 59 | 6 | 16% |
| 60 | 8 | 16% |
| 61 | 22 | 4% |
| 62 | 59 | 6% |
| 63 | 15 | 16% |
| 64 | 7 | 10% |
| 65 | 208 | 9% |
| 66 | 5 | 13% |
| 68 | 35 | 5% |
| 69 | 105 | 3% |
| 70 | 28 | 13% |
| 71 | 47 | 5% |
| 72 | 33 | 14% |
| 73 | 35 | 13% |
| 74 | 22 | 13% |
| 75 | 10 | 10% |
| 76 | 7 | 10% |
| 77 | 43 | 5% |
| 78 | 42 | 5% |
| 79 | 29 | 14% |
| 80 | 12 | 13% |
| 81 | 89 | 17% |
| 82 | 105 | 17% |
| 83 | 136 | 16% |
| 84 | 29 | 16% |
| 85 | 5 | 19% |
| 86 | 10 | 16% |
| 87 | 34 | 9% |
| 88 | 15 | 7% |
| 89 | 11 | 13% |
| 90 | 12 | 4% |
| 91 | 8 | 13% |
| 92 | 32 | 4% |
| 95 | 19 | 4% |
| 96 | 53 | 16% |
| 97 | 24 | 5% |

| | | |
|---|---|---|
| 99 | 58 | 11% |
| 100 | 30 | 9% |
| 101 | 35 | 5% |
| 102 | 36 | 3% |
| 103 | 18 | 5% |
| 104 | 17 | 9% |
| 105 | 5 | 14% |
| 106 | 61 | 5% |
| 107 | 75 | 16% |
| 108 | 8 | 15% |
| 109 | 3 | 3% |
| 110 | 1 | 7% |
| 111 | 2 | 12% |
| 112 | 2 | 13% |
| 113 | 2 | 14% |
| 114 | 3 | 16% |
| 115 | 2 | 4% |
| 116 | 3 | 15% |
| 117 | 1 | 13% |
| 118 | 3 | 14% |
| 119 | 3 | 13% |
| 120 | 2 | 13% |
| 121 | 1 | 4% |
| 122 | 32 | 16% |
| 123 | 6 | 9% |
| 124 | 68 | 4% |
| 125 | 7 | 13% |
| 126 | 29 | 14% |
| 200 | 11 | 10% |
| 201 | 30 | 14% |
| 202 | 5 | 4% |
| 203 | 51 | 15% |
| 204 | 252 | 16% |
| 205 | 68 | 15% |
| 206 | 7 | 16% |
| 207 | 37 | 17% |
| 208 | 10 | 18% |
| 209 | 305 | 17% |
| 210 | 15 | 17% |
| 211 | 73 | 12% |
| 212 | 25 | 4% |
| 214 | 60 | 15% |
| 215 | 81 | 17% |
| 216 | 23 | 8% |
| 217 | 106 | 13% |
| 218 | 33 | 13% |
| 219 | 9 | 13% |
| 220 | 37 | 19% |
| 221 | 46 | 14% |
| 222 | 146 | 16% |
| 223 | 157 | 18% |
| 224 | 66 | 13% |
| 225 | 37 | 4% |
| 227 | 143 | 5% |
| 228 | 3 | 10% |
| 229 | 10 | 13% |
| 230 | 7 | 13% |
| 231 | 24 | 13% |
| 232 | 82 | 15% |

| | | |
|---|---|---|
| 233 | 15 | 16% |
| 234 | 101 | 16% |
| 235 | 22 | 16% |
| 236 | 28 | 16% |
| 237 | 66 | 11% |
| 238 | 249 | 15% |
| 239 | 78 | 4% |
| 240 | 170 | 14% |
| 242 | 10 | 13% |
| 243 | 8 | 13% |
| 244 | 78 | 8% |
| 245 | 16 | 13% |
| 246 | 85 | 13% |
| 247 | 59 | 14% |
| 248 | 8 | 13% |
| 249 | 8 | 6% |
| 250 | 188 | 13% |
| 251 | 179 | 8% |
| 252 | 12 | 4% |
| 253 | 12 | 17% |
| 254 | 95 | 4% |
| 255 | 11 | 13% |
| 256 | 60 | 14% |
| 257 | 96 | 14% |
| 258 | 7 | 12% |
| 259 | 37 | 5% |
| 260 | 56 | 4% |
| 261 | 49 | 4% |
| 262 | 148 | 8% |
| 263 | 5 | 17% |
| 264 | 95 | 12% |
| 265 | 14 | 4% |
| 266 | 132 | 11% |
| 267 | 112 | 15% |
| 268 | 76 | 8% |
| 269 | 36 | 15% |
| 270 | 86 | 10% |
| 271 | 23 | 10% |
| 272 | 199 | 15% |
| 274 | 73 | 17% |
| 275 | 11 | 14% |
| 276 | 144 | 13% |
| 279 | 23 | 16% |
| 281 | 63 | 13% |
| 282 | 127 | 9% |
| 284 | 65 | 12% |
| 286 | 71 | 15% |
| 287 | 47 | 4% |
| 288 | 8 | 8% |
| 289 | 23 | 12% |
| 290 | 11 | 15% |
| 291 | 156 | 10% |
| 292 | 24 | 3% |
| 293 | 17 | 13% |
| 294 | 2 | 13% |
| 295 | 133 | 9% |
| 296 | 46 | 4% |
| 297 | 38 | 12% |
| 298 | 42 | 4% |

| | | |
|---|---|---|
| 299 | 25 | 13% |
| 300 | 23 | 15% |
| 301 | 1 | 16% |
| 302 | 15 | 12% |
| 303 | 11 | 16% |
| 304 | 23 | 17% |
| 305 | 67 | 18% |
| 306 | 24 | 19% |
| 307 | 36 | 17% |
| 308 | 29 | 18% |
| 309 | 10 | 18% |
| 310 | 16 | 18% |
| 311 | 11 | 18% |
| 312 | 6 | 18% |
| 313 | 159 | 18% |
| 314 | 20 | 18% |
| 315 | 5 | 17% |
| 318 | 156 | 8% |
| 319 | 5 | 18% |
| 320 | 14 | 18% |
| 321 | 27 | 16% |
| 322 | 17 | 16% |
| 323 | 11 | 16% |
| 324 | 28 | 19% |
| 325 | 15 | 18% |
| 326 | 9 | 18% |
| 327 | 5 | 19% |
| 328 | 202 | 17% |
| 329 | 3 | 18% |
| 330 | 6 | 18% |
| 331 | 26 | 16% |
| 332 | 38 | 17% |
| 333 | 50 | 18% |
| 335 | 118 | 17% |

| | | |
|---|---|---|
| 336 | 10 | 18% |
| 337 | 24 | 18% |
| 338 | 19 | 18% |
| 339 | 12 | 16% |
| 340 | 18 | 20% |
| 341 | 20 | 21% |
| 342 | 12 | 22% |
| 343 | 102 | 17% |
| 344 | 33 | 17% |
| 345 | 30 | 23% |
| 346 | 12 | 18% |
| 347 | 14 | 17% |
| 348 | 19 | 17% |
| 349 | 34 | 17% |
| 350 | 12 | 17% |
| 351 | 78 | 14% |
| 352 | 32 | 17% |
| 353 | 47 | 17% |
| 354 | 14 | 18% |
| 355 | 59 | 16% |
| 356 | 27 | 17% |
| 357 | 17 | 16% |
| 358 | 29 | 18% |
| 359 | 29 | 17% |
| 360 | 14 | 16% |
| 361 | 348 | 12% |
| 362 | 20 | 18% |
| 363 | 17 | 17% |
| 364 | 37 | 8% |
| 365 | 54 | 16% |
| 366 | 16 | 16% |
| 367 | 27 | 15% |

## Soil Productivity Trends

Soil quality in the project area is stable to trending upward. Most disturbed soils have lots of roots throughout the upper soil layers. Evidence of old compaction, evidence in soils with platey structure, have begun to recover from established root systems of vegetation and rodent burrows. Root depth within the project area ranged from 1.0 cm to 5.0 cm, with an average of 2.9 cm. Field observations revealed that on average, within units visited, units had 7% exposed mineral soil. Many legacy trails had an adequate amount of effective ground cover, while some trails and landings had exposed mineral soil due to soil bulk density being too high for root penetration. In most cases, skid trails and landings represent the greatest amount of legacy disturbance in the project area. Literature indicates that disturbed soils improve by means of plant growth, bioturbation, freeze/thaw cycles, wet/dry cycles, and organic matter additions, all of which naturally occur in the project area (Elliot et al., 1999). These natural processes effectively improve compacted soils over time (Lull, 1959). Compaction recovery rates are highly variable with an expected range of 10 to 70 years (Gonsior, 1983). Field observations showed that units surveyed had moderate to high soil recovery potential indicating high resiliency to disturbances. The target downed wood for dry ponderosa pine sites is 5 to 10 tons/acre and 7 to 15 tons/acre for mixed conifer sites for moderating soil productivity while minimizing fuel hazard (Brown et al., 2003; Graham et al., 1994). Monitoring of 30 units within the project, revealed that 52% of units visited had adequate downed wood for soil productivity, while 28% had less than adequate downed wood, and 21% had an excessive amount of down wood for the site. The average downed wood across units visited was 9.4 tons/acre. The average optimum level of fine organic matter is 21 to 30 percent (Graham et al., 1994), this equates to 2.5 to 5 cm of surface litter and humus, which provides a good indicator of healthy forest soil (Jain and Graham, 2009). Forest floor litter and duff depths were measured across survey units. Total organics in units

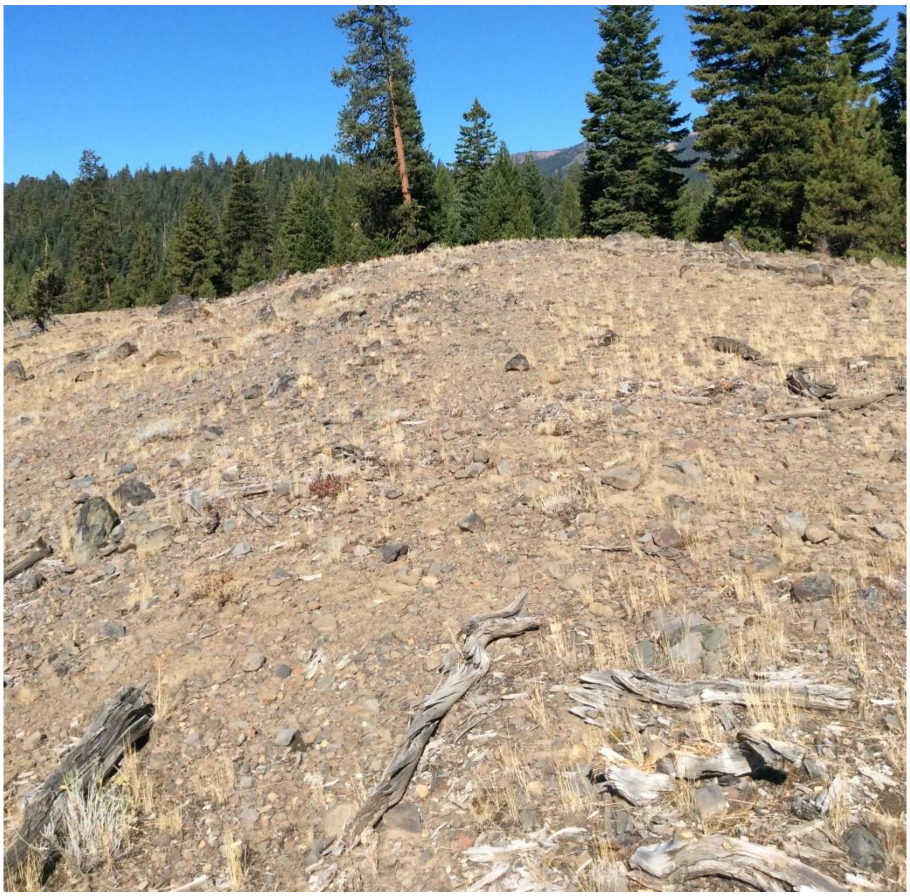
ranged from 1.0 to 4.0 cm, with an average of 2.2 cm.

## Droughty Soils

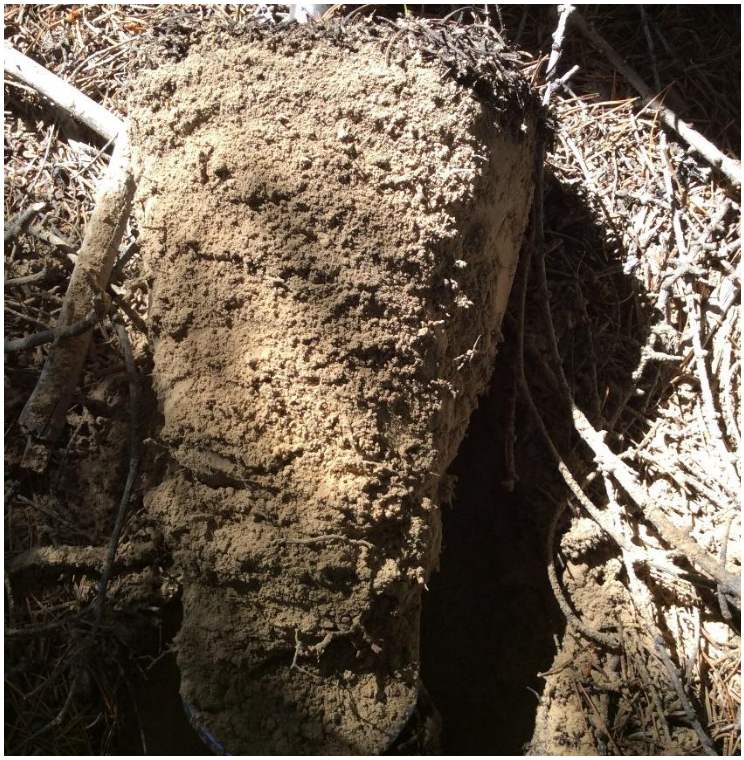
Due to fire suppression, many areas on the Wallowa-Whitman have become unsustainably overstocked. During low precipitation periods, when soil does not have the ability to supply moisture to support those overstocked conditions, drought stress occurs and forest health risks (e.g., insect and disease) increase. Some stands are currently managed at densities that may be unsustainable under projected climate variations and are considered to have reduced soil productivity (i.e., reduced ability to supply water and nutrients needed to sustain plant growth). Thinning of overstocked vegetation, with a focus on maintaining vegetation densities within the capacity of the soil to support productive growth, should be included in forested landscape management objectives. Restoration of soil moisture and plant community ecological processes is also an important aspect of adapting to climate change and creating resilient landscapes. There is currently 5,797 acres of forested stands on droughty soil types within the project area.

## Sensitive Soils

Dry meadows with shallow soils are considered sensitive soil types because of their shallow soil depth and inability to recover from disturbance events. There are dry meadows with shallow soils scattered throughout the project area. These areas are defined as having thin, rocky soils with drought tolerant plants (Johnson and Simon, 1987). These soils have more rock and clay than soils influenced by loess or volcanic ash. When located on concave surfaces, these soils are often saturated until mid to late July. Disturbance tends to disrupt the rock-moss-plant species. Care must be taken to avoid these areas when choosing landing sites and skid trail locations. The Wallowa-Whitman 1990 LRMP Standards and Guidelines specifically identify these soils and require avoidance and mitigation measures to provide protection. There are 836 acres of shallow soils within the project area.

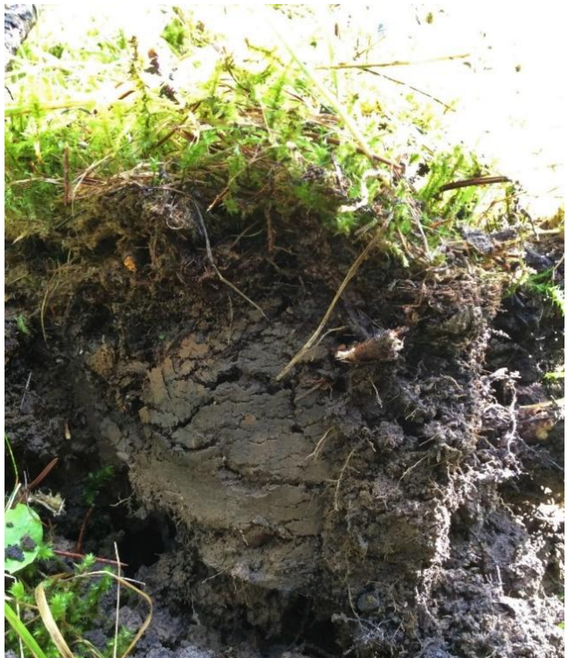


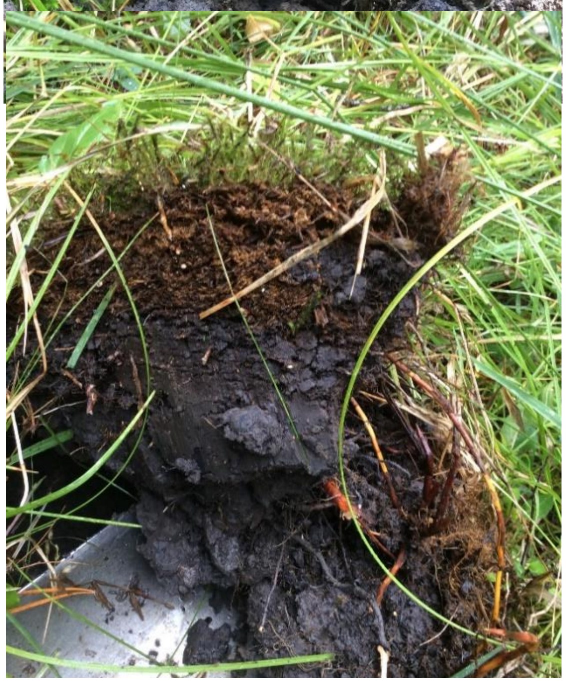
Thick ash cap soils are also considered a sensitive soil. Volcanic ash has a low bulk density and bearing strength, which enables a high water-holding capacity (Geist and Strickler, 1978; Geist et al., 1989). The low bulk density also increases the potential for rutting and compaction. In these areas, ground based equipment would be carefully managed to prevent ash cap loss and confined to period when soil is dry, frozen, or snow covered. There are 19,182 acres of thick ash cap soils within the project area. Vegetation will recover quickly reducing erosion, and in the case of pinegrass plant associations, the pinegrass mat helps hold the soil in place.



Sensitive soils contain an excess of soil moisture either yearlong or on a seasonal basis and have an udic soil moisture regime. Disturbance on these sensitive soils can lead to loss of productivity. Soils with udic soil moisture regimes require PDCs for protection and mitigation (Soil PDC 5). There are 20,673 acres of udic soils within the project area.

Hydric soils are wetland soils also considered sensitive, they are defined as a soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part (USDA NRCS, 2018). Hydric soils facilitate and regulate the flow of water between groundwater systems and surface water systems. Biogeochemical cycling is dependent on the combination of aerobic and anaerobic conditions in hydric soils. The capacity of hydric soils to retain water and develop anaerobiosis promotes specific plant communities and unique wildlife habitats. Wetlands are is defined in regulations, 16 U.S.C. Section 3801(a)(27): "as land that has – 1. Has a predominance of hydric soils, 2. Is inundated or saturated by surface or groundwater at a frequency and duration sufficient to support a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions, 3. Under normal circumstances supports a prevalence of such vegetation." These soils will be treated as a wetland according to PACFISH and Forest Plan definitions, which will prevent resource damage (See Aquatics Report for more information on RHCAs). There are 525 acres of hydric soils within the project area.





Low productivity soils have inherent soil properties that lower the soils ability to retain adequate organic matter reservoirs needed for nutrient cycling and maintenance of long-term site productivity. These soil types will have specific protections and mitigations to ensure site productivity is maintained (Soil PDC 16). There are 617 acres of low productivity soils in the project area.

## SOIL EROSION

Soil erosion is a natural process that can be accelerated by land management activities; it depends on soil texture, rock content, vegetative cover and slope. Erosion hazards can be ameliorated by operating on slopes less than 30 percent with good vegetative cover. Vegetation binds soil particles together with roots and vegetative cover and protects the soil surface from raindrop impact and dissipates the energy of overland flow. The dominant erosion risk for undisturbed soils in this project are low to moderate. Most of the project area is characterized by gentle slopes and soils with high infiltration rates. The high rock fragment content of most subsurface horizons also promotes water movement through the soils. Runoff from these soils is uncommon.

Existing annual soil loss for hillslopes within this project were modeled to determine baseline upland erosion rates. The WEPP model results estimated the mean average annual soil loss for all watersheds modeled, to be 0.33 tons per year (Table 7).

## SLOPE STABILITY

Table 5 provides acres of slope stability across the project area. Most of the project area is considered stable. There are 737 acres within the project area that been identified as existing landslide areas. There are 781 acres that may be prone to landslides. Any areas with slope instability will be field validated before any project activities occur. Most existing landslides are small in extent and are not currently active. Areas that are active are along roadways where the toe of the slope has been cut by the road. These areas typically require more road maintenance to clear out ditches and culverts.

**Table 5. Slope stability within the project area**

| Slope Stability in Project | Acres |
|---|---|
| Stable Areas | 28,223 |
| Potential Landslide Areas | 781 |
| Mapped Landslide Areas | 737 |

# ENVIRONMENTAL CONSEQUENCES

## ALTERNATIVE 1 – NO ACTION

### Soil Productivity

The No Action alternative would not cause short-term effects on the soil resource over and above existing condition. No additional road building, timber harvest, prescribed burning, or fuel reduction would disrupt natural soil processes.

#### Physical Soil Characteristics

The No Action alternative would not cause soil compaction, rutting, puddling, or soil displacement. Undisturbed soils would remain so. Soil productivity in areas where past timber management compacted soils would slowly improve as plant roots, soil organisms, and freeze-thaw events loosen the soil. Most soil disturbances would recover after 70 years (Gonsior, 1983). Sites that are slightly compacted would recover in fewer than 70 years. Displaced, rutted, and puddled soils would have reduced productivity for a longer time than compacted soils.

#### Organic Matter

Standing dead trees would eventually fall over and contribute coarse woody debris and additional organic material would be recruited through natural mortality. Fine-woody debris would remain on site. Soil organisms would decompose the organic materials adding humus to the soil. Nutrients associated with this material would slowly become available for plant growth. As the tree canopies close and shade the soil surface, decomposition rates would slow, allowing organic matter and nutrients to accumulate on the soil surface. This process would continue until another major disturbance, such as fire or a windstorm, opens the tree canopy and speeds up the recycling process again.

#### Soil Biological Activity

Microorganism populations would fluctuate with the changes in microclimate and supply of organic matter on the soil surface. These changes would be in response to the changing vegetation as a result of natural events such as fire, wind throw, and other sources of natural vegetation mortality. Any changes would be buffered by the capability of the soil microbial communities to adapt to changing conditions on very short time scales (Schmidt et al., 2007).

## Soil Erosion

No action would allow any current soil erosion to decrease as vegetation returns to soils that lack plant cover. Wildfires could cause short-term increase in soil erosion. Soil erosion rates would fluctuate with natural changes in vegetation and associated ground cover.

## Soil Stability

No action would not change the risk of mass failures within the project area. Most slopes are considered currently stable. Mass failures are unlikely with no management actions.

## ALTERNATIVE 2 AND 3

## Project Design Features and Mitigation Measures

1. In areas where **more than 20 percent** detrimental soil conditions exist from prior activities, the cumulative detrimental effects from project implementation and restoration must, at a minimum, not exceed the conditions prior to the planned activity and should move towards a net improvement in soil quality (R6 Soil Quality Standards) by rehabilitating landings and used skid trails as needed through de-compacting to bring post-activity DSCs to acceptable levels in each activity area.
2. In areas where **less than 20 percent** detrimental soil conditions exist from prior activities, the cumulative detrimental effect of the current activity following project implementation and restoration must not exceed 20 percent. In units expected to exceed 20 percent detrimental soil conditions:
    - Rehabilitate landings and used skid trails as needed thru de-compacting to bring post-activity DSCs to acceptable levels in each activity area.
    - If de-compacting is not feasible (i.e., shallow, clayey, rocky and/or topographic constraints) restrict harvest activities to winter harvest conditions.
    - If none of the above actions are feasible, then the particular treatment area should be excluded from mechanical activities.
3. Limit equipment operations to frozen, snow-covered or acceptable soil moisture conditions (as described in Appendix F. Limit machine pivots and turns, where possible.
    - **During the winter season** ground conditions shall meet at least one of the following criteria for machine operations:
        - Six inches of frozen ground,
        - Four inches of frozen ground with one foot of snow,
        - Two feet (>24 inches) or more of snow,
        - One-foot (>12 inches) slash mat in combination with one foot of snow, or
        - Soil moisture conditions acceptable for minimizing rutting or puddling of soils
    - Some “watch-out” situations include:
        - Machine break-through begins to occur
        - Equipment tracks sink deeply (half the width of the track) below the soil surface with one or two passes
        - Ruts greater than six inches deep form
        - Mid-day temperatures are forecast to rise above freezing
        - Surface melt occurs over still-frozen subsurface

4. Avoid operating on shallow soils (<25 cm soil depth) and meadows unless over frozen ground/snow. Shallow soils and clayey soils should not be used for temporary roads, skid trails, slash piles, or log landings; unless no other location is practical and there is an existing prism in which case equipment activity should remain within existing prism as much as possible.

5. Avoid early summer equipment operations on units with udic moisture regime (moist soils with inherent excess soil moisture either yearlong or on a seasonal basis). If this is not possible or there is evidence of lingering moisture present, operate on a bed of slash maintained at >12 inches to mitigate compaction and rutting.

6. Ground-based equipment should not operate on sustained slopes exceeding 30%, unless reviewed by soil specialist or hydrologist. Prioritize areas of slopes greater than 30% as leave areas within units.

   Designated skid trails should be spaced on average 100 feet apart, and the trails should average no more than 12 feet in width. Closer spacing due to complex terrain will be with Timber Sale administrator approval. Existing skid trails will be used as much as possible.

   - If equipment must leave designated trails for operational purposes, no more than two passes over any piece of ground is permitted.

   - Ensure that water control structures (water bars or slash surfacing, as approved by the Sale Administrator or COR) are installed and maintained on skid trails that have gradients of 10 percent or more; Ensure erosion control structures are stabilized and working effectively before spring runoff.

   When cut to length harvest systems are used, maintain an appropriate slash mat of at least 12” when possible during operations to prevent equipment weight from altering soil bulk density and causing displacement of effective ground cover. If unable to maintain an appropriate slash mat, impacts are expected to be the same as tractor logging

7. Whole-tree yarding methods should be avoided in shallow soils (<25cm), nutrient-poor (granitic soil, glacial outwash sands, many coarse-textured soils) soils or in sensitive areas. If not possible, backhaul slash and redistribute on skid trails to an average depth of 6 inches within the harvest area, and extend the time period for reentry to allow more time for nutrient inputs.

8. Use advanced logging systems where treatment is planned for continuous slopes greater than 30%. Advanced logging systems may include a variety of techniques including, but not limited to, cable yarding or other advanced logging systems where adequate protection against soil compaction and displacement can be demonstrated.

   - Use directional hand falling of trees and winching on slopes greater than 30% that cannot be reached by harvesting equipment from designated skid trails, as much as possible. Leading end suspension should be implemented when cabling or skidding material.
   - Skid trails or yarding corridors on slopes greater than 30% used by the purchaser should be reclaimed by applying appropriate erosion control measures such as the placement of effective ground cover in conjunction with, or in place of, water bars for rehabilitation.

   - Tethered logging harvest systems:
     - Short discontinuous pitches exceeding 30 percent should be discussed with a soil scientist or hydrologist but can be approved by the sale administrator.

- Treatment units where steep (>30%) slopes are continuous require field verification for activity approval by a soil scientist or hydrologist. Sale administrators may receive instruction for basic slope approval for sales.
- Ground equipment activity on continuous slopes exceeding 30 percent must be designed to function on steep slopes either on its own or tethered by a separate machine. If steep slope vehicles are not able to maintain traction and soil displacement from slipping tracks occurs regularly on a slope, steep slope activity shall stop. Limit side tracking and turning of equipment to limit soil displacement.
- Single passes with felling equipment on slopes 30 to 50 percent are acceptable. Preferably, single passes occur over slash, but not required. If additional passes are needed, maintain a minimum of 8 to 12 inches of slash.
- Cutting, bunching and skid trail spacing should be more than 50 feet apart edge to edge, except when converging at landings or avoiding obstacles.
- Equipment trails should avoid concentrating runoff and provide breaks in grade. They should be reclaimed by applying appropriate erosion control measures such as the placement of effective ground cover in conjunction with, or in place of, water bars for rehabilitation.
- Slash and organic material in trails should not be intentionally burned.

9. Commercial RHCA treatments will stay on existing roads and total suspension will be used to remove forest materials. Non-commercial RHCA treatments will be all hand thinned.
   - Slash should provide at least 65% effective ground cover and up to 8 tons of slash per acre. Slash piles should be burned when soil moisture is high, and piles are small (max size 4ft in height and 6ft in diameter) (Blue Mountain PDCs).
10. Signs of slope instability and mass movement include cracks in soil, tilted or bent trees, increased spring activity or newly wet ground, hummocky or uneven terrain, sunken or broken road beds, and/or a recent sag pond has formed that isn't human created. Consult engineering and soil resource specialist if these signs are present. Units identified as having slope instability will be field validated before implementation. If there are signs of slope instability or mass movement, these areas will receive a buffer in accordance to Blue Mountain PDCs.
11. Retain adequate supplies of coarse woody debris (CWD) (greater than three inches in diameter) to provide organic matter reservoirs for nutrient cycling and microbiotic (fungi and bacteria) habitat following completion of all project activities. Dry forest stands should have 5 to 10 tons per acre of coarse woody debris retained within the stand. Moist – mixed conifer stands should have 7 to 15 tons per acre of coarse woody debris retained within the stand.
   - In order to retain adequate organic matter reservoirs for nutrient cycling and maintenance of long-term site productivity, minimize disturbance and piling of decaying large woody debris during fuel treatments. Strive to maintain fine organic matter (commonly referred to as the duff layer) over at least 65 percent of an activity area following both harvest and post-harvest operations. Keep fine organic matter disturbance to a minimum if the potential natural plant community on site is not capable of producing fine organic matter over 65 percent of the area (Regional Soil Quality Guidelines / FSH 2090.11).
12. Prior to the seasons ending precipitation event, ensure necessary water control structures are installed and maintained on skid trails over 10% slope after all ground-disturbing activities. Ensure erosion

control structures are stabilized and working effectively and ensure that effective ground cover is left.

- In areas of general disturbance in ash soils, the top layer (A Horizon) should be pulled back over any disturbed surface to prevent permanent loss of productivity. (Pull berms back over disturbed surfaces)

- After completion of land management activities, the minimum effective ground cover (EGC) within each activity area within disturbed areas shall be in place to prevent erosion from exceeding background erosion rates for each of the four established erosion hazard classes: low, medium, high or very high (table below). Effective ground cover is defined as the basal area of perennial vegetation, plus duff, litter and coarse fragments (greater than 2mm sizes), including tree crowns and shrubs that are in direct contact with the ground.

| | Minimum Effective Ground Cover | |
|---|---|---|
| **Erosion Hazard Class** | **1st Year** | **2nd Year** |
| **Low** | 20-30% | 30-40% |
| **Medium** | 30-45% | 40-60% |
| **High** | 45-60% | 60-75% |
| **Very High** | 60-90% | 75-90% |

13. In areas where de-compacting is prescribed, de-compact to a depth sufficient to ameliorate the presence of detrimental soil compaction (usually between 2 and 12 inches). Discontinue de-compacting where large rocks are continually brought to the soil surface. If a change in soil color is noticed by the operator, operate at a shallower depth that prevents topsoil and subsoil from mixing. Skid trails requiring rehab on slopes > 30% should use erosion control methods that prevent channelized flow. Picking up ripping tines periodically down the slope.

    - Effective ground cover for all de-compacting treatments should take advantage of harvest slash. If no suitable organic material is available, then weed free straw or other equivalent erosion control measures should be applied on slopes exceeding 15%, adjacent to waterways and ditches (within 100 feet), prior to seasons ending precipitation event. See BMP AqEco-2 for additional information.

14. Non-system or legacy road templates will be used for temporary roads to the greatest extent possible. Creation of new temporary roads will be minimized. Where needed, locate to fit the terrain, and follow natural contours and minimize adverse effects to soil, water quality and riparian resources. Placement of new temporary roads should be on deep soils, as possible and avoid temporary roads on clay-dominated soils. Any new temporary roads within RHCAs will be approved by a hydrologist and sale administrator prior to constructing.

    Temporary road mitigation measures include:

    - Locate temporary roads on flat terrain and benches where possible to reduce cut/fill construction and sedimentation risks
    - Provide adequate drainage through proper location, out sloping and installing water bars as appropriate
    - Install suitable storm water and erosion control measures (water bars, out slope) to stabilize disturbed areas and waterways before seasonal shutdown of project operations or when severe or successive storms are expected.
    - Upon completion of use, rehabilitate temporary roads by removing any culverts, decompacting the road surface and covering all disturbed areas with slash. Rehab may also include re-

contouring the natural slope profile as possible, masking entrances, and seeding with native plant seed to promote effective ground cover.

- Avoid burning of slash and organic material incorporated into road rehabilitation during prescribed fire activities.

15. Grapple pile operations would use the same skid trails as harvest operations where possible. Mechanical fuel operations would adhere to ground-based equipment PDCs mentioned above.

    Where feasible, pile slash on sites already disturbed by logging activities (e.g. skid trails, landings, and roads) in order to minimize additional detrimental soil impacts from burning. Avoid locating slash piles on shallow soils (<25cm). Piling slash should not occur above or below culverts or drainages to prevent sediment delivery. If piling fuels near a culvert or drainage, pile fuels away from the culvert or drainage high water flow. Limit hand pile size to less than 50 square feet to reduce organic horizon loss and limit soil heating. Pile burning when duff is moist or wet can reduce organic matter loss and soil heating.

    When using a boom-mounted implement, operator shall plan off-trail travel paths to make full use of the machine's capability (e.g., using the full boom reach of the machine) to limit ground disturbance and minimize the number of off-trail passes.

    Reclaim all machine-built fire lines by redistributing displaced topsoil and unburned woody debris over the disturbed surface as needed after burn has been completed. Install water bars on fire lines using the following guideline: 5-15% slope every 150 feet, 16-35% slope every 40 feet, 36-60% slope every 30 feet, and >60% slope every 15 feet. On slopes less than 15%, water bars may not be needed if adequate amounts of slash are available.

    Slash and organic material incorporated into road rehabilitation should not be intentionally burned. Slash and organic material in trails from tethered harvest systems should not be intentionally burned.

16. Adequate amounts of slash should be left within the unit in order to retain fine organic matter on low productivity soils with inherently lower ability to retain adequate organic matter reservoirs. If Regional Soil Quality Standards and Guidelines are unable to be met because the stand is incapable of producing enough slash, all slash should be left untreated.

## Direct and Indirect Effects – Alternative 2 and 3

### Soil Productivity

#### Physical Soil Characteristics

##### *Non-Commercial Thinning*

Non-commercial treatments will involve hand thinning and/or piling. These treatments frequently produce slash accumulations that are piled and burned to meet desired conditions. Hand thinning and piling would not generate detrimental soil conditions, but the associated grapple piling and pile-burning could. Hand pile-burning could result in minor changes to soil structure where temperatures between 220 and 460 C are generated (DeBano et al., 1998; Busse, 2014). Burning slash piles when soil and duff moisture is high, reduces soil temperatures (Frandsen and Ryan, 1986) (Soil PDC 15). No significant effects to soil bulk density, infiltration capacity, or soil moisture content are expected from hand pile-burning (Seymour et al., 2004).

Grapple piling is proposed for both treatments where slopes are less than 30%. Grapple piling and subsequent pile-burning generates approximately 3% DSC (Bliss, 2004; Hanson, 2005). Use of ground-based equipment to grapple pile would have direct and indirect effects on soil physical characteristics within the boundaries of proposed activity areas. However, project PDCs to limit equipment operations to dry, frozen or snow-covered ground conditions would greatly reduce these potential effects. Soil compaction is reduced when soils are dry (below field capacity, i.e. below optimum water content) (McNabb et al., 2001; Starsev et al., 2001). Rutting and puddling are most often associated with ground-based mechanical equipment operation on wet soils (Williamson et al., 2000). Tracked equipment is generally used for grapple piling which minimizes changes to physical soil properties and reduces the aerial extent of impacts (Moghaddas and Stephens, 2008). The same mitigation and operational guidelines are required for grapple piling to reduce the potential for soil productivity losses. Slope limitations and soil moisture guidelines would be applied to minimize DSC caused by equipment movement. The same designated trail systems would be used in post-commercial thinning treatments as were used in the commercial harvest, which would reduce the extent of disturbance.

### *Commercial Thinning*

Commercial thinning treatments proposed will utilize both ground-based and cable yarding systems. Commercial thinning operations would result in direct and indirect effects on soil physical characteristics within the boundaries of Alternative 2 and 3 activity areas (Table 6). Most detrimental effects would be concentrated on the proposed skid trails, temporary roads, and landings within or associated with ground-based activity areas. Minimizing the area occupied by landings and skid trials to reduce the detrimental effects on soil productivity from changes in physical soil properties is recommended in several papers (Garland, 1983; Page-Dumroese, 2006; Williamson et al., 2000; Amaranthus 1996). Ground disturbing activities would be laid out to occupy less than 20 percent of each activity unit including system roads. System roads in this project area average 3.4 percent of the analysis area. Landings occur approximately every 10 acres of an activity area and occupy a space of approximately ¼ acre. Acres of skid trails are assumed to be 1/10$^{th}$ of the unit and only half are considered to produce new DSCs. The other half are assumed to be on old skid trails. New skid trail DSCs are calculated by taking half of the estimated skid acres and dividing that value by the unit acres. For tractor harvest, that number will always be 5%. In addition to using designated skid trails and landings, there would be potential to reduce soil effects further by limiting equipment operation on skid trails to when soils are dry (below field capacity, i.e. below optimum water content) (McNabb, 2001; Startsev et al., 2001). Rutting and puddling are most often associated with logging on wet soils (Williamson et al., 2000). Most summer logging would occur when soils are drier than field capacity. By operating on low soil moisture conditions, we have the potential to reduce the amount of detrimental disturbance from ground-based operations (Soil PDC 3). Limiting machine pivots and turns, where possible reduces the amount of soil displacement and compaction that occurs (Soil PDC 3).

Cut-to-length harvest systems utilize a slash mat that is created when harvesting and processing trees from a designated equipment trail. The equipment is then able to ride on top of the slash mat reducing compaction, displacement, and rutting (Allen and Adams, 1997). Cut-to-length harvest systems can afford some flexibility to operators at the beginning and end of the operating season, since an adequate slash mat can prevent compaction, displacement, and rutting with increased soil moisture (highly variable depending on spring and fall weather). Minimal direct and indirect effects from this treatment would be expected only if the harvest is able to produce adequate slash loads to elevate the equipment above the soil, with at least 12" of green slash to prevent the equipment weight from altering soil bulk density and displacement of effective ground cover (Soil PDC 6). If those conditions can't be met, direct and indirect impacts on physical soil characteristics are expected to be the same as other ground-based harvest systems.

Cable yarding operations would result in direct and indirect effects on soil physical characteristics within the boundaries of the proposed activity areas (Purser and Cundy, 1992). Effects would be less than those from ground-based operations. Skyline yarding disturbs 2 to 8% of the soil in a unit. Based on field monitoring data, skyline yarding creates 1% detrimental disturbance from soil displacement (McIver et al., 2000). Skyline landings are typically 100-1,000 square feet and create 1% detrimental disturbance. When skyline slash is piled and burned it creates 1% detrimental soil disturbance from burn effects (Bliss, 2004).

### Tethered Logging

Tethered logging is proposed in this project. Tethered logging systems are recent to the Pacific Northwest and to the Forest Service. They have been used in Europe and New Zealand but recently made its way into Washington and Oregon. This logging system uses a cable to a fixed object or another piece of heavy equipment to help harvesting equipment navigate steep ground. The cable attaches a piece of equipment, usually a harvester or forwarder, to an anchor point, to assist the machine on steep slopes. This enables harvesting equipment to travel on slopes that are otherwise too steep for most ground-based equipment (30% slope or greater), increasing access to areas that were previously restricted due to slope. Tethered systems are interesting to land managers for this reason and more importantly, for improvements in operator safety. Traditional steep slope cable logging relies on workers cutting trees by hand and manually setting chokers, exposing themselves to falling trees and other hazards. The tethered logging method allows workers to operate inside the cab of a machine which mitigates some of those risks. Safety, increased access, and increasing areas of restoration are potential benefits of this method.

Minimal research exists on the effects of tethered logging to soils. Since it is making its way onto the public lands, land managers and resource specialists need to better understand the soil impacts associated with tethered logging. Specifically, soil scientists and hydrologists are interested in learning how ground-based equipment associated with this new technology might affect the physical soil/hydrological conditions on steep slopes. It is well known that steep slopes are vulnerable to soil erosion and that detrimental soil effects increase with steeper slopes. On Forest Service lands, most ground-based equipment is limited to 30% slope or less, tethered equipment can operate on much steeper slopes. There are concerns for soil compaction, rutting, and soil displacement under these conditions. Deep ruts can develop while operating on steep slopes, which allow for accumulation of water runoff and subsequent soil erosion. There are additional concerns for soil mixing and topsoil displacement due to track slippage, as well as keeping within Region 6 - Soil Quality Standards.

Research suggests that soil disturbance may be reduced by tethering on steep slopes. Sessions and Leshchinsky (2017) discuss tethered logging and conclude, theoretically, that under the right soil conditions, soil disturbance should be reduced. Visser and Stampfer (2015) state “that it can be assumed that a tethered assist system will reduce soil disturbance through reduced slippage of the tracks compared with that for untethered vehicles”. In addition, researchers at Oregon State University (OSU) are currently studying steep slope logging, focusing on safety and assessing environmental impacts. Their initial results suggest that cable assisted equipment results in less compaction due to the decrease in ground pressure (Green, 2017). However, the research is still ongoing and additional evidence is needed to fully evaluate the effects in regard to soil productivity and hydrologic function.

Initial DSC monitoring of tethered cut-to-length winter harvest system on the Colville showed results similar to what is typically seen in winter logged, cut to length harvest treatments. The fully tethered units averaged a soil detrimental percentage of 5.3 %, the partially tethered units 7 %, and the non-tethered unit 13%. This data suggests the tethered equipment resulted in less detrimental conditions. On the Fremont-Winema National Forest in south-central Oregon, soil disturbance monitoring was completed on a timber sale unit which was thinned in the summer of 2016 utilizing a tethered harvester and forwarder on wheel tracks (Rone 2017). Average slopes in the unit were approximately 20 to 60%, with soils consisting of coarse pumice which were operated on in dry soil moisture conditions. Soil disturbance monitoring in 2016 found 18% detrimental soil disturbance (G. Rone, pers. comm.). Initial direct soil disturbance was dominated by soil displacement over compaction, which is related to the coarse, non-cohesive properties of the pumice soil in the unit. Some other operational concerns that were observed were machine side tracking and turning impacts, the disintegration of slash mats, and converging and side-by-side skid trails.

This project will implement pre and post monitoring of any units identified for tethered logging in the summer of 2021. Any units identified as having slope instability will be excluded from treatment. Project design criteria and mitigations have been developed based on observations on other forests in the region and can be found in Soil PDC 8. Observations on other forests in the region showed lower DSCs than traditional ground based commercial thinning. Out of caution, the DSCs for this project were calculated to reflect traditional ground-based thinning impacts until future monitoring is completed in Blue Mountain forests.

#### Riparian Habitat Conservation Area Treatments

Riparian areas that have been affected by past management activities are proposed for thinning to promote deficient broadleaf species (cottonwood, aspen and willow) and future large diameter trees. are strategically place where existing roadbeds exist in the riparian habitat conservation area.

Commercial thinning would take place on that uphill side of roads and equipment would be limited to staying on the roadbed and reaching into a unit. Total suspension will be used to remove material is required and will reduce impacts to soils. Noncommercial thinning in RHCA's will be thinned by hand removing trees up to 9 inches DBH. Direct and indirect effects to physical soil characteristics may be less in RHCAs because of PDCs designed to reduce ground-disturbing impacts and by operating under suitable ground moisture conditions (Soil PDC 9). Burning of piles could result in minor changes to soil structure if temperatures between 220 and 460 C are generated (DeBano et al., 1998), as discussed above in NCT and PCT treatment effect.  Burning slash piles when soil and duff moisture is high, reduces soil temperatures (Frandsen and Ryan, 1986) (Soil PDC 9).

#### Temporary Roads

In Alternative 2 and 3, there are up to 4.5 miles of temporary roads proposed in this project, with 4.3 miles of new temporary road construction. Average clearing width is assumed to be 12 feet for temporary roads, therefore they would create 1.5 acres of DSC per mile (Table 6). Upon completion of use, all temporary roads will be rehabbed and will follow mitigation measures listed in (Soil PDC 14).

Recontouring activities would not ameliorate the long-term impacts to soil productivity immediately but would improve soil conditions compared to those of an existing or abandoned road. The establishment of vegetation and associated additions of organic matter would encourage recovery over time. De-compacting and re-contouring each provide a suitable seed bed for native forest vegetation while increasing soil hydraulic conductivity, organic matter, total carbon, and total nitrogen (Lloyd et al., 2013). These conditions with the addition of woody material as effective ground cover would likely accelerate the recovery of soil productivity (Soil PDC 12 and 14) (Luce, 1997).

Non-system roads within the project were mapping and totaled approximately 30 miles (43 acres). This project will prioritize KV funds for rehabilitation of non-system historic or user-created road templates that still exist on the landscape within the project area.

#### Summary

Since the 1990 Forest Plan, the level of concern for maintaining soil productivity has greatly increased. This increase has been accompanied with implementation of management practices that protect the soil. These changes include the use of excavators instead of dozers for mechanical site preparation, use of designated skid trails, operating when soils are dry or when winter conditions would protect soil productivity, harvester-forwarder systems, and use of slash layers to reduce effects on skid trails. In addition, vegetation management projects are audited for compliance with BMPs and are monitored as specified in the NEPA decision, both of which contribute to better results.

Table 6 shows the expected new and total DSCs for proposed action alternatives in this project. The final DSCs were calculated by adding existing DSCs with the new DSCs expected to result from the proposed activities. Alternatives 2 has 63 units and Alternative 3 has 31 units that are expected to exceed the standard threshold of 20 percent detrimental soil conditions. Soil rehabilitation activities would occur after ground-based activities are complete and the contractor would be required to decompact landings and used or old skid trails as needed to bring DSCs below 20% (Soil PDC 2). If decompacting is not feasible then equipment would only operate under winter harvest conditions (Soil PDC 2). If none of these actions are feasible, then the particular treatment area would be excluded from mechanical activities. All action alternatives will ensure that soil productivity will move toward a net improvement in soil quality. Additional protection of the soil resource would be afforded by having ground-based operations only when soils are dry, snow covered, or frozen. Grapple piling and burning generates minimal DSC and is prescribed in NCT and PCT treatments. Hand treatments would not be expected to result in any additional detrimental impacts.

This project will implement pre and post monitoring of any units identified for tethered logging. Any units identified as having slope instability will be excluded from treatment. Project design criteria and mitigations have been developed based on observations on other forests in the region and can be found in Soil PDC 8. Observations on other forests in the region showed lower detrimental impacts than ground based commercial thinning. Out of caution, the DSCs for this project were calculated to reflect ground-based thinning impacts until future monitoring is completed in Blue Mountain forests.

Upon completion of use, all temporary roads will be rehabbed. Non-system or legacy road templates will be used for temporary roads to the greatest extent possible. Creation of new temporary roads will be minimized. Where temporary roads are needed, they will be located to fit the terrain and minimize adverse effects to soil, water quality and riparian resources.

Several studies discuss the effectiveness of subsoiling as a soil restoration activity. Seedling survival and growth can be improved by 39 percent after decompacting soils (Froehlich and McNabb, 1983). Subsoiling restores biological processes that are reduced by soil compaction (Dick et al., 1988). In general, tilling or scarifying a compacted soil improves productivity by reducing the resistance of soil to root penetration and providing improved soil drainage and aeration to enhance seedling establishment and tree growth (Bulmer, 1998). These conditions also improve the environment for soil microorganisms. Soil restoration is not the immediate result of ripping, planting, or any other activity. The goal of soil restoration is to create favorable conditions for impaired soils to begin the recovery process.

**Table 6. New Detrimental Soil Conditions for Alternative 2 and 3**

| Unit | Skid Trail Contribution | | Piling and Burning | | Landings | | Temporary Roads | | New DSC | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Alt 2 | Alt 3 | Alt 2 | Alt 3 | Alt 2 | Alt 3 | Alt 2 | Alt 3 | Alt 2 | Alt 3 |
| 1 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 2 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 3 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 1% | 10% | 11% |
| 4 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 5 | 5% | Drop | 2% | Drop | 3% | Drop | 1% | Drop | 11% | Drop |
| 6 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 3.1% | 10% | 13% |
| 7 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 8 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 10 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 1% | 10% | 10% |
| 11 | 5% | Drop | 2% | Drop | 3% | Drop | 1% | Drop | 11% | Drop |
| 12 | 0% | Drop | 1% | Drop | 0% | Drop | 0% | Drop | 1% | Drop |
| 13 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 14 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 16 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 17 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 18 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 19 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 20 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 21 | 5% | 5% | 2% | 2% | 3% | 3% | 3% | 3% | 13% | 13% |
| 22 | 5% | 5% | 2% | 2% | 3% | 3% | 1% | 1% | 11% | 11% |
| 23 | 5% | 5% | 2% | 2% | 3% | 3% | 1% | 1% | 10% | 10% |
| 24 | 5% | Drop | 2% | Drop | 3% | Drop | 1% | Drop | 11% | Drop |
| 25 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 26 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 27 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 28 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 29 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 30 | 5% | 5% | 2% | 2% | 3% | 3% | 1% | 1% | 10% | 10% |
| 31 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 32 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 33 | 5% | 5% | 2% | 2% | 3% | 3% | 2% | 2% | 11% | 11% |
| 34 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 35 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 36 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 37 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 38 | 0% | Drop | 1% | Drop | 0% | Drop | 0% | Drop | 1% | Drop |
| 39 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 40 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 41 | 1% | 5% | 1% | 2% | 1% | 3% | 0% | 1% | 3% | 10% |
| 42 | 5% | Drop | 2% | Drop | 3% | Drop | 1% | Drop | 10% | Drop |
| 43 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 44 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 45 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 46 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 47 | 1% | Drop | 1% | Drop | 1% | Drop | 0% | Drop | 3% | Drop |
| 48 | 1% | Drop | 1% | Drop | 1% | Drop | 0% | Drop | 3% | Drop |
| 49 | 1% | Drop | 1% | Drop | 1% | Drop | 0% | Drop | 3% | Drop |
| 50 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 51 | 5% | Drop | 2% | Drop | 3% | Drop | 2% | Drop | 11% | Drop |
| 52 | 5% | 5% | 2% | 2% | 3% | 3% | 1% | 3% | 11% | 12% |
| 53 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 54 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 55 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 56 | 1% | 5% | 1% | 2% | 1% | 3% | 0% | 0% | 3% | 10% |
| 57 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 58 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 59 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 60 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 61 | 1% | Drop | 1% | Drop | 1% | Drop | 0% | Drop | 3% | Drop |
| 62 | 0% | Drop | 1% | Drop | 0% | Drop | 0% | Drop | 1% | Drop |
| 63 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 64 | 0% | Drop | 1% | Drop | 0% | Drop | 0% | Drop | 1% | Drop |
| 65 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 1% | 10% | 10% |
| 66 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 68 | 0% | Drop | 1% | Drop | 0% | Drop | 0% | Drop | 1% | Drop |
| 69 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 1% | 10% | 10% |
| 70 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 71 | 0% | Drop | 1% | Drop | 0% | Drop | 0% | Drop | 1% | Drop |
| 72 | 5% | Drop | 2% | Drop | 3% | Drop | 1% | Drop | 11% | Drop |
| 73 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 74 | 1% | 5% | 1% | 2% | 1% | 3% | 1% | 1% | 4% | 11% |
| 75 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 76 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 77 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 78 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 79 | 1% | 5% | 1% | 2% | 1% | 3% | 1% | 2% | 4% | 11% |
| 80 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 81 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 82 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 83 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 84 | 1% | 5% | 1% | 2% | 1% | 3% | 0% | 0% | 3% | 10% |
| 85 | 5% | 5% | 2% | 2% | 3% | 3% | 4% | 4% | 14% | 14% |
| 86 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 87 | 1% | Drop | 1% | Drop | 1% | Drop | 0% | Drop | 3% | Drop |
| 88 | 0% | Drop | 1% | Drop | 0% | Drop | 0% | Drop | 1% | Drop |
| 89 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 90 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 91 | 1% | Drop | 1% | Drop | 1% | Drop | 0% | Drop | 3% | Drop |
| 92 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 95 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 96 | 1% | Drop | 1% | Drop | 1% | Drop | 0% | Drop | 3% | Drop |
| 97 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 99 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 100 | 0% | Drop | 1% | Drop | 0% | Drop | 0% | Drop | 1% | Drop |
| 101 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 102 | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 1% | 1% |
| 103 | 0% | Drop | 1% | Drop | 0% | Drop | 0% | Drop | 1% | Drop |
| 104 | 0% | Drop | 1% | Drop | 0% | Drop | 0% | Drop | 1% | Drop |
| 105 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 106 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 107 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 108 | 0% | Drop | 1% | Drop | 0% | Drop | 0% | Drop | 1% | Drop |
| 109 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 110 | 0% | Drop | 0% | Drop | 0% | Drop | 0% | Drop | 0% | Drop |
| 111 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 112 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 113 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 114 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 115 | 5% | Drop | 2% | Drop | 3% | Drop | 6% | Drop | 15% | Drop |
| 116 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 117 | 0% | Drop | 0% | Drop | 0% | Drop | 0% | Drop | 0% | Drop |
| 118 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 119 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 120 | 0% | 0% | 0% | 0% | 0% | 0% | 7% | 0% | 7% | 0% |
| 121 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 122 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 123 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 124 | 5% | Drop | 2% | Drop | 3% | Drop | 0% | Drop | 10% | Drop |
| 125 | 1% | Drop | 1% | Drop | 1% | Drop | 4% | Drop | 7% | Drop |
| 126 | 5% | 5% | 2% | 2% | 3% | 3% | 0% | 0% | 10% | 10% |
| 200 | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 1% | 1% |
| 201 | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 1% | 1% |
| 202 | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 1% | 1% |
| 203 | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 1% | 1% |
| 204 | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 1% | 1% |
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In Alternative 2, there are 2,049 acres of droughty soil types that will be treated. In Alternative 3, there are 1,322 acres of droughty soil types that will be treated. Treatment on droughty soils will help restore soil moisture and plant community ecological processes to adapt to climate change and build forest resiliency.

There are 237 acres of shallow soils (<25cm), considered sensitive, within Alternative 2 activity areas. In Alternative 3, there are 171 acres of shallow soils (<25cm), considered sensitive. Project design criteria specifies shallow, clayey soils and meadows will be avoided unless over ground/snow conditions. Shallow soils won’t be used for skid trails, slash piles, or log landings unless no other location is practical and there is an existing prism, in which case ground-based equipment will remain within the existing prism as much as possible (Soil PDC 4 and 7). Shallow soils are often clay dominated and hold onto moisture and are not appropriate for road use (Soil PDC 4). Operation on these soils will only occur during frozen ground/snow or dry conditions to mitigate compaction and rutting (Soil PDC 3 and 4).

Alternative 2 has 7,500 acres of thick ash cap soils. Alternative 3 has 4,491 acres of thick ash cap soils. These soils are characterized with low bulk density, high porosity, and high water-holding capacity. They tend to be non-cohesive and because of their relatively low strength, are highly susceptible to both vibratory and compressive compaction. Controlling compaction involves use of low impact equipment selection, use of designated skid trails, and limitation of operations to dry seasons or when the ground is frozen. Ground-based activities on ash soils will be mitigated by only operating when ground conditions are dry, frozen, or snow covered (Soil PDC 3).

Alternative 2 has 7,991 acres of soils with an excess of soil moisture either yearlong or on a seasonal basis. Alternative 3 has 4,904 acres of sensitive soils with an excess of soil moisture either yearlong or on a seasonal basis. These soils have an increased potential for compaction and deep rutting and require special design criteria. Spring and early summer harvest on these soils will be avoided, and if this is not possible, ground-based equipment will operate on a bed of slash maintained at >12 inches to mitigate compaction and rutting as much as possible (Soil PDC 5).

In Alternative 2, there are 120 acres of hydric soils, which are wetland soils formed under saturated conditions. In Alternative 3, there are 105 acres of hydric soils, which are wetland soils formed under saturated conditions. When identified during implementation, these soils would be buffered appropriately as wetlands to meet national and regional laws and regulations (see Aquatics Report).

### Organic Matter

All proposed treatments would leave varying amounts of organic matter on site. Reductions in organic matter content reverse quickly as vegetation is established. Organic debris accumulates on the surface and roots grow and are decomposed in the soil. These organic materials break down, release nutrients and improve the quality of the soil by improving its structure, reducing compaction and other DSCs. Coarse woody debris (greater than three inches in diameter) would be retained at approximately 5 to 10 tons per acre on dry ponderosa pine sites and 7 to 15 tons per acre on mixed conifer sites (Adapted from DeBano, Neary, and Ffolliott, 1998) (Soil PDC 11). The total amount of nutrients on a site would likely be reduced where organic matter would be removed or displaced. However, plant available nutrients mineralized from organic matter would increase due to increased incoming solar radiation and soil moisture. These conditions would accelerate the decomposition of the remaining organic matter and the release of plant-available nutrients in the treated stands (Harvey et al., 1994). After project implementation, competition between trees would be reduced because fewer trees would remain on the sites. This situation could result in more available nutrients and water for remaining trees, potentially contributing great growth, vigor and disease resistance (Power et al., 2005). Nutrients in soil and organic matter, are not the only nutrients available to forest vegetation. In logging followed by low-severity broadcast burning, there would be no long-term depletion of nitrogen reserves because lost nitrogen would be more than replenished by inputs from precipitation and by biological nitrogen fixation over a rotation of 100 to 150 years (Jurgensen et al., 1981).

#### *Commercial Thinning and Mechanical Slash Treatment*

These treatments would leave a large portion of the existing stand on site. Units proposed for grapple pile burning or prescribed fire would leave nutrients associated with the slash on site, to be used by the remaining forest vegetation. Grapple piling associated with fuel treatments would reduce organic material on sites while reducing hazardous fuel loads (USDA, 2005). Physical forest floor impacts would be limited to track deformation and minor amounts of displacement (less than 100 square feet). A variety of organic material would remain on the site after project implementation.

Under Alternative 2, there are 197 acres of low productivity soils proposed for treatment, not capable of producing or maintaining adequate fine organic matter if slash is removed. Under Alternative 3, there are 107 acres of low productivity soils proposed for treatment, not capable of producing or maintaining adequate fine organic matter if slash is removed. Special design criteria will mitigate potential loss of organics on these soils, by ensuring adequate amounts of fine slash is left on site (Soil PDC 16).

#### *Hand Non-Commercial and Post-Commercial Thinning*

Limiting hand pile size to less than 50 square feet could reduce surface organic horizon loss and limit soil heating. Pile burning when duff is moist or wet can reduce organic matter loss and soil heating (Soil PDC 15).

The amount of nutrients lost as particulate matter would be minor. Ash from burned hand piles would contain nutrients available to emergent vegetation, but no significant increases in nitrogen and phosphorus are anticipated (Seymour et al., 2005).

#### *Prescribed Fire*

The effect of fire on soil is described as burn severity, which depends on the duration of burning and the intensity (Certini, 2005). Long-duration burns tend to reach higher temperatures and penetrate deeper into soil, resulting in more soil microbial kill and consumption of soil organic matter (ibid.). These burns result from burning of heavy ground fuel, such as with downed logs and large slash piles. Short duration burning could be associated with fast-moving wildfire that blackens all the trees but leaves some of the forest floor intact. This usually results in low-to-moderate burn severities on the ground, with heat only penetrating a few centimeters (Harford et al., 1992). Prescribed fire activities that result in predominantly low-to-moderate burn severities would preserve soil productivity (Harvey et al., 1993). The amount of nutrients available to plants would increase as a result of the burning. Areas burned under conditions that produce light or moderate burn severity would vegetate quickly due to viable seeds or roots that could produce more plants and the benefit of microorganisms and nutrients remaining on site (Ryan and Noste, 1985; Harmon, 1992; Neary et al., 2005). Post-fire vegetation response would utilize available nutrients, reducing nutrient leaching. Native forest vegetation would remain on the site, including some of the existing trees.

The ultimate goal of this effort is to maximize the intended vegetative response while minimizing resource effects. Fire intensity represents the magnitude of produced heat (Keeley, 2009). It is distinct from burn severity. Fire management personnel would design burn plans and implement burning activities to minimize the occurrence of high-burn severity, while achieving burn intensities adequate to meet objectives.

#### *Summary*

All proposed units would leave live vegetation. Most of the living grass, forb, and shrub components would be retained in all of the proposed activity areas. Many live trees would remain on all of the sites. The material that remains in all of the activity areas would provide an active, microorganism-rich organic layer on the soil surface.

Limiting hand pile size to less than 50 square feet could reduce surface organic horizon loss and limit soil heating. Pile burning when duff is moist or wet can reduce organic matter loss and soil heating (Soil PDC 15).

Under Alternative 2, there are 197 acres of low productivity soils not capable of producing or maintaining adequate fine organic matter if slash is removed. Under Alternative 3, there are 107 acres of low productivity soils not capable of producing or maintaining adequate fine organic matter if slash is removed. Special design criteria will mitigate potential loss of organics on these soils by ensuring fine slash is left on site (Soil PDC 16).

### Soil Biological Activity

The variety of organic matter left on the proposed activity areas would benefit soil microorganisms by providing substrate and habitat. Microbial measures in harvest areas are expected to meet, or exceed, levels in unharvested stands within 40 years (Page-Dumroese et al., 2015). All alternatives would leave both dead and live trees. All alternatives and all proposed activity areas would have less than 20 percent of the area detrimentally disturbed. Many areas would be undisturbed by equipment. These areas would be a source of propagules in disturbed sites. Both action alternatives describe the amount of live and dead trees to be left in proposed activity areas.

Post-fire recovery of soil microorganisms occurs rapidly, frequently resulting in population levels greater than before the fire (Jurgensen et al., 1979). Less disturbed areas of soil play an important role in inoculating soil lacking or having reduced populations of soil microorganisms (Borchers and Perry, 1990). Areas within burns that are left unburned, adjacent undisturbed areas, large woody debris and soils with minor amounts of disturbance contain propagules for fungi, bacteria and other soil organisms. Wind, animals and other agents can freely disperse these propagules (Borchers and Perry, 1990).

Forest productivity depends on mycorrhizae for survival. Mycorrhizal fungi, like all fungi, are aerobes associated with the organic matter components of surface soils. Presumably, management activities that reduce aeration or soil organic matter (mechanical slash piling, and slash burning) will reduce mycorrhiza activity (Perry and Rose, 1983). Soil compaction, puddling, rutting, and displacement reduce gas exchange and could potentially affect soil microorganism survival. Favorable habitat for soil organisms will be maintained since all proposed activity areas would be designed to reduce soil disturbance to meet Region 6 Soil Quality Standards.

#### *Summary*

Because the amount of detrimental physical soil changes would be minimized and because organic matter in various forms would remain on the proposed units, the effects to soil microorganisms would be minor. Soil microorganisms are mobile. They can quickly re-colonize disturbed sites from adjacent, undisturbed sites. A variety of organic matter would remain on all sites, including living trees and other forest vegetation. In addition, the organic layer on the soil surface would be retained over at least 80 percent of the area, providing habitat and nutrients for soil microorganisms.

## Soil Erosion

Displacement and erosion, the loss of topsoil, is a long-term and perhaps a permanent loss of soil productivity. However, management practices outline in the Project Design Criteria would reduce the occurrence of displacement and erosion to within the Region 6 Soil Quality Standards. Where there is a risk of soil erosion, it would be minimized by implementing the following management practices:

- Reducing the area where equipment operates,
- Locating landings on relatively flat ground that can be properly drained,
- Locating skid trails on slopes less than 30 percent that have soils with a low or moderate erosion hazard,
- Using erosion control features, such as water bars, replanting, and placing slash on disturbed soils.

Alternative 2 and 3 treatments for each hillslope were modeled to determine potential erosion after both thinning and prescribed fire treatments. Alternative 2 and 3 mean average annual soil loss is 0.33 tons per year (Table 7). By way of comparison, the average annual erosion on Oregon cropland in 2015 was 1.7 tons per acre per year. A ton of soil spread across an acre would be as thick as a dime.

Erosion potential is highest within the first year following ground-disturbance, wildfire, or prescribed fire. This project will be implemented across approximately 10 to 15 years. This makes it very likely that actual erosion rates across the project area will be less than modeled.

**Table 7. Potential Soil Erosion modeled in WEPP for Alternative 2 and 3**

| Alternative | Potential Erosion Rate (lb/acre/yr) | Potential Total Hillslope Erosion (tons/yr) |
|---|---|---|
| No Action | 0.07 | 0.3 |
| Alt 2 | 0.07 | 0.3 |
| Alt 3 | 0.07 | 0.3 |

Sediment from the permanent transportation system has direct effects on water quality and is not a component of the soil quality assessment process. These effects are evaluated in the Hydrology Section of this EA.

### Commercial Thinning and Mechanical Slash Treatment

Management activities that leave organic matter on the soil surface reduce soil erosion potential (Megahan, 1981; Megahan, 1986; Robichaud et al., 1993). The dominant surface erosion hazard when the forest floor has been disturbed, with ground-based proposed is slight to moderate.

Alternative 2 has 441 acres and Alternative 3 has 283 acres of soil types (>1 acre in size) with high erosion hazard. Alternative 2 has 2,000 acres and Alternative 3 has 1,081 acres of soil types (>1 acre in size) with very high erosion hazard.

Together, soils with high and very high erosion potential make up 34% of ground-based activities in Alternative 2 and 31% of ground-based activities in Alternative 3. To reduce surface erosion potential, disturbed areas within these units would be required to have a minimum of 60 to 90 percent effective ground cover following cessation of any soil-disturbing activities (R6 Soil Quality Standard) (Soil PDC 12). Any increase in overland flow from existing areas of compacted soil is likely to be buffered by existing forest floor and/or new accumulations of woody debris.

#### Hand Non-Commercial and Post-Commercial Thinning

Maintenance of infiltration rates and effective ground cover of soils is necessary to prevent erosion. The lack of compactive forces would not result in a significant reduction in infiltration rates over undisturbed soil. Although reductions in effective ground cover would be expected at burn pile locations, the lack of accompanying increase in overland flow and the rapid establishment of live plant cover would reduce short-term soil erosion. No long-term soil erosion is anticipated from this treatment. Soil erosion would be unlikely to occur because of the small diameter thinning treatments.

#### Prescribed Fire

Landscape burning would leave many areas unburned, providing a buffer for any increase in overland flow. Post-fire vegetative response would be rapid, regardless of burn severity and areas that burn intensely would have sufficient organic material and vegetative response to reduce risks to soil erosion (Robichaud and Waldrop, 1994; Robichaud and Brown, 1999; Lentile et al., 2007). Soil erosion rates would decrease, as vegetation and effective ground cover are re-established. It is recommended that this project utilizes extended burn periods so that only portions of the watershed are incrementally impacted over the intended time frame. This should allow burned areas to recover and potential sediment movement or delivery to be minimal, especially if riparian buffers are maintained.

#### Temporary Roads

Erosion is expected from temporary roads, where native surfaces are exposed to rainfall impact and overland flow. Alternatives 2 has 3.9 miles and Alternative 3 has 2.5 miles of temporary roads proposed on soils with high erosion hazard. These roads would likely have short-term increases of soil erosion above 0.3 tons per acre per year. Erosion rates would decrease, as roads are rehabbed immediately following use. All ground-disturbing activities are required to have the minimum effective ground cover after completion of activities, in order to prevent erosion from exceeding background erosion rates (Soil PDC 12 and 14).

#### Road Maintenance and Reconstruction

Road maintenance is planned for most open roads in the project. Maintenance will also occur on stored roads needed to access designated treatment areas. Road maintenance activities include replacement of existing culverts, cleaning road drainage features including ditches, culverts and dips, full depth reconditions of the road prism, road base stabilization, fill slope stabilization, clearing and brushing of existing right of way, removal of tree stumps within the travel way, road grading, and placing new road surface aggregate. Culvert installations and replacements would cause some short-term soil erosion during the construction phase but would result in improved road drainage and a reduction of road failure risk during high flow events (Burroughs, 1989). Removal of tree stumps, referred to as stump grubbing, is done when opening a closed road, or an open system road that has trees within the road prism. Stump grubbing is only done in order to allow for road grading within drivable road template. It is expected to cause some short-term soil erosion, like road grading.

Realignment requires removal of enough of the old road prism to allow the surface and subsurface water drainage networks to regain their natural function and pattern. Heavy equipment (dozers, compactors, graders, and excavators) are used for removal and reconstruction. Benefits of realigning a road include reduced risks of road failures from catastrophic storm events. Realignment can cause considerable disturbance to an area and short-term increased soil erosion but would result in improved road drainage and reduced road failure risk during high flow events. Erosion control methods will be used after completion of work. Proposed realignment in this project is less than 500 feet in length.

### Soil Stability

A majority of the project area has high rates of slope stability and are well-suited for proposed activities. The majority of ground-based treatments are planned for areas with slopes less than 30 percent, which greatly reduces the risk of mass failures. The occurrence of any mass-failure occurring on well-suited slopes as a result of implementation of proposed actions is unlikely. The angle of repose for soils within the project area is 19 degrees, or 34% slope, just above Forest Plan standards for ground-based equipment. All areas with landslide potential will be field validated. If areas are verified as having landslide potential, Blue Mountain PDCs and a buffer will be applied to these areas to mitigate any potential mass movement.

#### Proposed Treatments

In Alternative 2, there are 663 acres of proposed treatments in areas with landslide potential. In Alternative 3, there are 357 acres of proposed treatments on existing landslide areas. Prior to implementation all treatments areas with landslide potential will be field validated.

#### Road Activities

In Alternative 2 and 3, there are 0 miles of temporary roads proposed in landslide prone areas. There are system roads that do transect some of landslide prone areas and they have and will continue to require more frequent ditch cleanout and road maintenance.

## Cumulative Effects

The risk of cumulative effects was assessed within each proposed activity area. Cumulative effects consist of the impacts from all past, present, future, and proposed activities overlapping in time and space within the project area. The estimated cumulative effects for each activity area from implementation of an action alternative are displayed in Table 8. These predicted cumulative detrimental soil condition values are based on implementation of all required Project Design Criteria (PDC). See associated PDCs for the Soil Resource in Chapter 2.

Noxious Weed Management and the W-W Invasive Species ROD will overlap in time and space with this project, however, does not create any ground disturbance and therefore in unmeasurable. Blue Fly Fuels reduction will not overlap within Sheep Creek units, soil impacts may occur within Blue Fly units however that has been previously analyzed. Winam-Frazier OHV trails fall within the project area. OHV use is permitted on most roads within the project area and cross-country. Cross-country travel and OHV could create limited areas of soil compaction, displacement and puddling but would be too limited in aerial extent to measure and unlikely to measurably increase in the foreseeable future. Trail maintenance could create limited areas of soil displacement and puddling but would be too limited in aerial extent to measure, and unlikely to measurably increase in the foreseeable future. The Trail Wildlife Enhancement Closure Area would reduce OHV and cross-country travel within the closure area for part of the year, which reduces the potential for soil impacts. Dispersed camping occurs primarily during hunting season and can occur throughout the project area since there is currently no restriction on cross-country motorized travel. Dispersed camping could create limited areas of soil compaction and displacement but primarily would occur within already disturbed areas or would be too limited in aerial extent to measure.

Firewood cutting and Danger Tree Removal could create limited areas of soil compaction, displacement, and puddling from skidding trees and off-road wood retrieval but would be too limited in aerial extent to measure. Road maintenance occurs only within the road prism right-of-way is not part of the productive land base, therefore soil productivity concerns are not applicable. National BMPs will be implemented to ensure erosion control measures and slope stability. Road maintenance improves long-term road drainage and sediment delivery concerns. There is currently active grazing in the Sheep Creek Ranch Allotment. There is potential for additional access for cattle into project units that were previously inaccessible, however impacts would be too limited in extent to measure. Most grazing impacts are within riparian areas and water development areas. Grazing impacts could occur within areas of riparian proposed activities; however, this is limited in extent. Grazing impacts near water development areas could have limited areas of compaction or trampling of soil, however the potential soil impact would be too limited in aerial extent to be counted in DSC calculations (Page 3 of Region 6 Supplement No. 2500.98-1, USDA Forest Service, 1998). Private land activities don’t overlap with project activities, so direct and indirect soil impacts are not expected within NFS lands. These ongoing and reasonably foreseeable activities are not expected to add to adverse cumulative watershed effects for the soil resource because of their limited aerial extent.

**Table 8. Cumulative Effects for Both Action Alternatives**

| Unit | Existing Condition DSC Percent | Vegetation Treatments | | Temporary Roads | | Cumulative DSC Percent | |
|---|---|---|---|---|---|---|---|
| | | Alt 2 | Alt 3 | Alt 2 | Alt 3 | Alt 2 | Alt 3 |
| 1 | 13% | 10% | 10% | 0% | 0% | 23% | 23% |
| 2 | 13% | 10% | 10% | 0% | 0% | 23% | 23% |
| 3 | 4% | 10% | 10% | 0% | 1% | 14% | 15% |
| 4 | 4% | 10% | Drop | 0% | Drop | 14% | Drop |
| 5 | 13% | 10% | Drop | 1% | Drop | 24% | Drop |
| 6 | 16% | 10% | 10% | 0% | 3% | 25% | 28% |
| 7 | 6% | 10% | Drop | 0% | Drop | 16% | Drop |
| 8 | 13% | 10% | 10% | 0% | 0% | 23% | 23% |
| 10 | 4% | 10% | 10% | 0% | 1% | 14% | 14% |
| 11 | 13% | 10% | Drop | 1% | Drop | 24% | Drop |
| 12 | 9% | 1% | Drop | 0% | Drop | 10% | Drop |
| 13 | 10% | 10% | 10% | 0% | 0% | 20% | 20% |
| 14 | 5% | 10% | 10% | 0% | 0% | 14% | 14% |
| 15 | 13% | 10% | 10% | 0% | 0% | 23% | 23% |
| 16 | 13% | 10% | Drop | 0% | Drop | 23% | Drop |
| 17 | 5% | 10% | 10% | 0% | 0% | 14% | 14% |
| 18 | 13% | 10% | 10% | 0% | 0% | 23% | 23% |
| 19 | 4% | 10% | 10% | 0% | 0% | 14% | 14% |
| 20 | 4% | 10% | 10% | 0% | 0% | 13% | 13% |
| 21 | 5% | 10% | 10% | 3% | 3% | 18% | 18% |
| 22 | 9% | 10% | 10% | 1% | 1% | 20% | 20% |
| 23 | 7% | 10% | 10% | 1% | 1% | 18% | 18% |
| 24 | 21% | 10% | Drop | 1% | Drop | 32% | Drop |
| 25 | 17% | 10% | Drop | 0% | Drop | 26% | Drop |
| 26 | 17% | 10% | Drop | 0% | Drop | 26% | Drop |
| 27 | 17% | 10% | Drop | 0% | Drop | 26% | Drop |
| 28 | 17% | 10% | Drop | 0% | Drop | 26% | Drop |
| 29 | 17% | 10% | Drop | 0% | Drop | 26% | Drop |
| 30 | 13% | 10% | 10% | 1% | 1% | 24% | 24% |
| 31 | 16% | 10% | 10% | 0% | 0% | 25% | 25% |
| 32 | 16% | 10% | 10% | 0% | 0% | 25% | 25% |
| 33 | 7% | 10% | 10% | 2% | 2% | 18% | 18% |
| 34 | 14% | 10% | 10% | 0% | 0% | 24% | 24% |
| 35 | 16% | 10% | Drop | 0% | Drop | 26% | Drop |

| Unit | Existing Condition DSC Percent | Vegetation Treatments | | Temporary Roads | | Cumulative DSC Percent | |
|---|---|---|---|---|---|---|---|
| 36 | 13% | 10% | 10% | 0% | 0% | 22% | 22% |
| 37 | 14% | 10% | 10% | 0% | 0% | 23% | 23% |
| 38 | 14% | 1% | Drop | 0% | Drop | 15% | Drop |
| 39 | 16% | 10% | Drop | 0% | Drop | 25% | Drop |
| 40 | 16% | 10% | Drop | 0% | Drop | 25% | Drop |
| 41 | 16% | 3% | 10% | 0% | 1% | 19% | 26% |
| 42 | 16% | 10% | Drop | 1% | Drop | 26% | Drop |
| 43 | 5% | 10% | Drop | 0% | Drop | 14% | Drop |
| 44 | 6% | 10% | 10% | 0% | 0% | 15% | 15% |
| 45 | 8% | 10% | 10% | 0% | 0% | 18% | 18% |
| 46 | 16% | 10% | Drop | 0% | Drop | 25% | Drop |
| 47 | 9% | 3% | Drop | 0% | Drop | 12% | Drop |
| 48 | 8% | 3% | Drop | 0% | Drop | 11% | Drop |
| 49 | 9% | 3% | Drop | 0% | Drop | 12% | Drop |
| 50 | 13% | 10% | Drop | 0% | Drop | 23% | Drop |
| 51 | 17% | 10% | Drop | 2% | Drop | 28% | Drop |
| 52 | 9% | 10% | 10% | 1% | 3% | 20% | 21% |
| 53 | 16% | 10% | Drop | 0% | Drop | 26% | Drop |
| 54 | 16% | 10% | Drop | 0% | Drop | 26% | Drop |
| 55 | 16% | 10% | Drop | 0% | Drop | 26% | Drop |
| 56 | 10% | 3% | 10% | 0% | 0% | 13% | 20% |
| 57 | 16% | 10% | Drop | 0% | Drop | 26% | Drop |
| 58 | 18% | 10% | Drop | 0% | Drop | 27% | Drop |
| 59 | 16% | 10% | Drop | 0% | Drop | 26% | Drop |
| 60 | 16% | 10% | Drop | 0% | Drop | 26% | Drop |
| 61 | 4% | 3% | Drop | 0% | Drop | 7% | Drop |
| 62 | 6% | 1% | Drop | 0% | Drop | 7% | Drop |
| 63 | 16% | 10% | 10% | 0% | 0% | 26% | 26% |
| 64 | 10% | 1% | Drop | 0% | Drop | 11% | Drop |
| 65 | 9% | 10% | 10% | 0% | 1% | 19% | 19% |
| 66 | 13% | 10% | Drop | 0% | Drop | 23% | Drop |
| 68 | 5% | 1% | Drop | 0% | Drop | 6% | Drop |
| 69 | 3% | 10% | 10% | 0% | 1% | 13% | 14% |
| 70 | 13% | 10% | Drop | 0% | Drop | 23% | Drop |
| 71 | 5% | 1% | Drop | 0% | Drop | 6% | Drop |
| 72 | 14% | 10% | Drop | 1% | Drop | 24% | Drop |
| 73 | 13% | 10% | 10% | 0% | 0% | 23% | 23% |
| 74 | 13% | 3% | 10% | 1% | 1% | 17% | 24% |
| 75 | 10% | 10% | 10% | 0% | 0% | 20% | 20% |
| 76 | 10% | 10% | 10% | 0% | 0% | 20% | 20% |
| 77 | 5% | 10% | 10% | 0% | 0% | 15% | 15% |
| 78 | 5% | 10% | 10% | 0% | 0% | 15% | 15% |
| 79 | 14% | 3% | 10% | 1% | 2% | 17% | 25% |
| 80 | 13% | 10% | 10% | 0% | 0% | 23% | 23% |
| 81 | 17% | 10% | 10% | 0% | 0% | 26% | 26% |
| 82 | 17% | 10% | 10% | 0% | 0% | 27% | 27% |
| 83 | 16% | 10% | 10% | 0% | 0% | 25% | 25% |
| 84 | 16% | 3% | 10% | 0% | 0% | 19% | 26% |
| 85 | 19% | 10% | 10% | 4% | 4% | 32% | 32% |
| 86 | 16% | 10% | 10% | 0% | 0% | 26% | 26% |
| 87 | 9% | 3% | Drop | 0% | Drop | 12% | Drop |
| 88 | 7% | 1% | Drop | 0% | Drop | 8% | Drop |
| 89 | 13% | 10% | 10% | 0% | 0% | 23% | 23% |
| 90 | 4% | 10% | Drop | 0% | Drop | 14% | Drop |
| 91 | 13% | 3% | Drop | 0% | Drop | 16% | Drop |
| 92 | 4% | 10% | Drop | 0% | Drop | 14% | Drop |
| 95 | 4% | 10% | Drop | 0% | Drop | 13% | Drop |
| 96 | 16% | 3% | Drop | 0% | Drop | 19% | Drop |

| Unit | Existing Condition DSC Percent | Vegetation Treatments | | Temporary Roads | | Cumulative DSC Percent | |
|---|---|---|---|---|---|---|---|
| 97 | 5% | 10% | Drop | 0% | Drop | 14% | Drop |
| 99 | 11% | 10% | Drop | 0% | Drop | 20% | Drop |
| 100 | 9% | 1% | Drop | 0% | Drop | 10% | Drop |
| 101 | 5% | 10% | Drop | 0% | Drop | 14% | Drop |
| 102 | 3% | 1% | 1% | 0% | 0% | 4% | 4% |
| 103 | 5% | 1% | Drop | 0% | Drop | 6% | Drop |
| 104 | 9% | 1% | Drop | 0% | Drop | 10% | Drop |
| 105 | 14% | 10% | Drop | 0% | Drop | 24% | Drop |
| 106 | 5% | 10% | Drop | 0% | Drop | 14% | Drop |
| 107 | 16% | 10% | Drop | 0% | Drop | 25% | Drop |
| 108 | 15% | 1% | Drop | 0% | Drop | 16% | Drop |
| 109 | 3% | 10% | Drop | 0% | Drop | 13% | Drop |
| 110 | 7% | 0% | Drop | 0% | Drop | 7% | Drop |
| 111 | 12% | 0% | 0% | 0% | 0% | 12% | 12% |
| 112 | 13% | 10% | 10% | 0% | 0% | 23% | 23% |
| 113 | 14% | 10% | 10% | 0% | 0% | 24% | 24% |
| 114 | 16% | 10% | Drop | 0% | Drop | 25% | Drop |
| 115 | 4% | 10% | Drop | 6% | Drop | 20% | Drop |
| 116 | 15% | 10% | 10% | 0% | 0% | 24% | 24% |
| 117 | 13% | 0% | Drop | 0% | Drop | 13% | Drop |
| 118 | 14% | 0% | 0% | 0% | 0% | 14% | 14% |
| 119 | 13% | 0% | 0% | 0% | 0% | 13% | 13% |
| 120 | 13% | 0% | 0% | 7% | 0% | 21% | 13% |
| 121 | 4% | 0% | 0% | 0% | 0% | 4% | 4% |
| 122 | 16% | 10% | 10% | 0% | 0% | 26% | 26% |
| 123 | 9% | 10% | Drop | 0% | Drop | 18% | Drop |
| 124 | 4% | 10% | Drop | 0% | Drop | 13% | Drop |
| 125 | 13% | 3% | Drop | 4% | Drop | 21% | Drop |
| 126 | 14% | 10% | 10% | 0% | 0% | 23% | 23% |
| 200 | 10% | 1% | 1% | 0% | 0% | 11% | 11% |
| 201 | 14% | 1% | 1% | 0% | 0% | 15% | 15% |
| 202 | 4% | 1% | 1% | 0% | 0% | 5% | 5% |
| 203 | 15% | 1% | 1% | 0% | 0% | 16% | 16% |
| 204 | 16% | 1% | 1% | 0% | 0% | 17% | 17% |
| 205 | 15% | 2% | 2% | 0% | 0% | 17% | 17% |
| 206 | 16% | 2% | Drop | 0% | Drop | 18% | Drop |
| 207 | 17% | 1% | 2% | 0% | 0% | 18% | 19% |
| 208 | 18% | 1% | 2% | 0% | 0% | 19% | 20% |
| 209 | 17% | 2% | 2% | 0% | 0% | 19% | 19% |
| 210 | 17% | 1% | 2% | 0% | 0% | 18% | 19% |
| 211 | 12% | 2% | 2% | 0% | 0% | 14% | 14% |
| 212 | 4% | 2% | 2% | 0% | 0% | 6% | 6% |
| 214 | 15% | 1% | 1% | 0% | 0% | 16% | 16% |
| 215 | 17% | 1% | 1% | 0% | 0% | 18% | 18% |
| 216 | 8% | 2% | 2% | 0% | 0% | 10% | 10% |
| 217 | 13% | 1% | 1% | 0% | 0% | 14% | 14% |
| 218 | 13% | 1% | 1% | 0% | 0% | 14% | 14% |
| 219 | 13% | 1% | 1% | 0% | 0% | 14% | 14% |
| 220 | 19% | 1% | 1% | 0% | 0% | 20% | 20% |
| 221 | 14% | 2% | 2% | 0% | 0% | 16% | 16% |
| 222 | 16% | 1% | 1% | 0% | 0% | 17% | 17% |
| 223 | 18% | 1% | Drop | 0% | Drop | 19% | Drop |
| 224 | 13% | 1% | 1% | 0% | 0% | 14% | 14% |
| 225 | 4% | 1% | 1% | 0% | 0% | 5% | 5% |
| 227 | 5% | 1% | 1% | 0% | 0% | 6% | 6% |
| 228 | 10% | 1% | 1% | 0% | 0% | 11% | 11% |
| 229 | 13% | 1% | 1% | 0% | 0% | 14% | 14% |
| 230 | 13% | 2% | 2% | 0% | 0% | 15% | 15% |

| Unit | Existing Condition DSC Percent | Vegetation Treatments | | Temporary Roads | | Cumulative DSC Percent | |
|---|---|---|---|---|---|---|---|
| 231 | 13% | 2% | 2% | 0% | 0% | 15% | 15% |
| 232 | 15% | 2% | 2% | 0% | 0% | 17% | 17% |
| 233 | 16% | 2% | Drop | 0% | Drop | 18% | Drop |
| 234 | 16% | 1% | 1% | 0% | 0% | 17% | 17% |
| 235 | 16% | 2% | 2% | 0% | 0% | 18% | 18% |
| 236 | 16% | 2% | Drop | 0% | Drop | 18% | Drop |
| 237 | 11% | 2% | 2% | 0% | 0% | 13% | 13% |
| 238 | 15% | 1% | 1% | 0% | 0% | 16% | 16% |
| 239 | 4% | 1% | 1% | 0% | 0% | 5% | 5% |
| 240 | 14% | 2% | 2% | 0% | 0% | 16% | 16% |
| 242 | 13% | 1% | Drop | 0% | Drop | 14% | Drop |
| 243 | 13% | 1% | Drop | 0% | Drop | 14% | Drop |
| 244 | 8% | 1% | Drop | 0% | Drop | 9% | Drop |
| 245 | 13% | 2% | 2% | 0% | 0% | 15% | 15% |
| 246 | 13% | 2% | 2% | 0% | 0% | 15% | 15% |
| 247 | 14% | 2% | 2% | 0% | 0% | 16% | 16% |
| 248 | 13% | 1% | Drop | 0% | Drop | 14% | Drop |
| 249 | 6% | 1% | 1% | 0% | 0% | 7% | 7% |
| 250 | 13% | 1% | 1% | 0% | 0% | 14% | 14% |
| 251 | 8% | 2% | 2% | 0% | 0% | 10% | 10% |
| 252 | 4% | 2% | 2% | 0% | 0% | 6% | 6% |
| 253 | 17% | 2% | 2% | 0% | 0% | 19% | 19% |
| 254 | 4% | 1% | 1% | 0% | 0% | 5% | 5% |
| 255 | 13% | 1% | 1% | 0% | 0% | 14% | 14% |
| 256 | 14% | 2% | 2% | 0% | 0% | 16% | 16% |
| 257 | 14% | 2% | 2% | 0% | 0% | 16% | 16% |
| 258 | 12% | 2% | 2% | 0% | 0% | 14% | 14% |
| 259 | 5% | 1% | 1% | 0% | 0% | 6% | 6% |
| 260 | 4% | 1% | 1% | 0% | 0% | 5% | 5% |
| 261 | 4% | 1% | Drop | 0% | Drop | 5% | Drop |
| 262 | 8% | 2% | 2% | 0% | 0% | 10% | 10% |
| 263 | 17% | 1% | 1% | 0% | 0% | 18% | 18% |
| 264 | 12% | 2% | 2% | 0% | 0% | 14% | 14% |
| 265 | 4% | 1% | 1% | 0% | 0% | 5% | 5% |
| 266 | 11% | 2% | 2% | 0% | 0% | 13% | 13% |
| 267 | 15% | 2% | 2% | 0% | 0% | 17% | 17% |
| 268 | 8% | 1% | 1% | 0% | 0% | 9% | 9% |
| 269 | 15% | 1% | 1% | 0% | 0% | 16% | 16% |
| 270 | 10% | 1% | 1% | 0% | 0% | 11% | 11% |
| 271 | 10% | 1% | 1% | 0% | 0% | 11% | 11% |
| 272 | 15% | 2% | 2% | 0% | 0% | 17% | 17% |
| 274 | 17% | 2% | 2% | 0% | 0% | 19% | 19% |
| 275 | 14% | 1% | 1% | 0% | 0% | 15% | 15% |
| 276 | 13% | 2% | 2% | 0% | 0% | 15% | 15% |
| 279 | 16% | 2% | 2% | 0% | 0% | 18% | 18% |
| 281 | 13% | 2% | 2% | 0% | 0% | 15% | 15% |
| 282 | 9% | 1% | 1% | 0% | 0% | 10% | 10% |
| 284 | 12% | 2% | 2% | 0% | 0% | 14% | 14% |
| 286 | 15% | 2% | 2% | 0% | 0% | 17% | 17% |
| 287 | 4% | 2% | 2% | 0% | 0% | 6% | 6% |
| 288 | 8% | 2% | 2% | 0% | 0% | 10% | 10% |
| 289 | 12% | 2% | 2% | 0% | 0% | 14% | 14% |
| 290 | 15% | 1% | 1% | 0% | 0% | 16% | 16% |
| 291 | 10% | 1% | 1% | 0% | 0% | 11% | 11% |
| 292 | 3% | 2% | 2% | 0% | 0% | 5% | 5% |
| 293 | 13% | 1% | 1% | 0% | 0% | 14% | 14% |
| 294 | 13% | 2% | 2% | 0% | 0% | 15% | 15% |
| 295 | 9% | 1% | 1% | 0% | 0% | 10% | 10% |

| Unit | Existing Condition DSC Percent | Vegetation Treatments | | Temporary Roads | | Cumulative DSC Percent | |
|---|---|---|---|---|---|---|---|
| 296 | 4% | 1% | 1% | 0% | 0% | 5% | 5% |
| 297 | 12% | 2% | 2% | 0% | 0% | 14% | 14% |
| 298 | 4% | 2% | 2% | 0% | 0% | 6% | 6% |
| 299 | 13% | 1% | 1% | 0% | 0% | 14% | 14% |
| 300 | 15% | 2% | 2% | 0% | 0% | 17% | 17% |
| 301 | 16% | 1% | Drop | 0% | Drop | 17% | Drop |
| 302 | 12% | 1% | 1% | 0% | 0% | 13% | 13% |
| 303 | 16% | 2% | Drop | 0% | Drop | 18% | Drop |
| 304 | 17% | 2% | Drop | 0% | Drop | 19% | Drop |
| 305 | 18% | 1% | 1% | 0% | 0% | 19% | 19% |
| 306 | 19% | 2% | Drop | 0% | Drop | 21% | Drop |
| 307 | 17% | 1% | 1% | 0% | 0% | 18% | 18% |
| 308 | 18% | 2% | Drop | 0% | Drop | 20% | Drop |
| 309 | 18% | 1% | Drop | 0% | Drop | 19% | Drop |
| 310 | 18% | 2% | Drop | 0% | Drop | 20% | Drop |
| 311 | 18% | 1% | Drop | 0% | Drop | 19% | Drop |
| 312 | 18% | 1% | Drop | 0% | Drop | 19% | Drop |
| 313 | 18% | 1% | Drop | 0% | Drop | 19% | Drop |
| 314 | 18% | 2% | Drop | 0% | Drop | 20% | Drop |
| 315 | 17% | 2% | Drop | 0% | Drop | 19% | Drop |
| 318 | 8% | 2% | 2% | 0% | 0% | 10% | 10% |
| 319 | 18% | 2% | Drop | 0% | Drop | 20% | Drop |
| 320 | 18% | 2% | Drop | 0% | Drop | 20% | Drop |
| 321 | 16% | 2% | Drop | 0% | Drop | 18% | Drop |
| 322 | 16% | 2% | Drop | 0% | Drop | 18% | Drop |
| 323 | 16% | 2% | 2% | 0% | 0% | 18% | 18% |
| 324 | 19% | 2% | Drop | 0% | Drop | 21% | Drop |
| 325 | 18% | 1% | Drop | 0% | Drop | 19% | Drop |
| 326 | 18% | 1% | Drop | 0% | Drop | 19% | Drop |
| 327 | 19% | 1% | 1% | 0% | 0% | 20% | 20% |
| 328 | 17% | 2% | 2% | 0% | 0% | 19% | 19% |
| 329 | 18% | 1% | Drop | 0% | Drop | 19% | Drop |
| 330 | 18% | 2% | Drop | 0% | Drop | 20% | Drop |
| 331 | 16% | 1% | Drop | 0% | Drop | 17% | Drop |
| 332 | 17% | 1% | Drop | 0% | Drop | 18% | Drop |
| 333 | 18% | 2% | Drop | 0% | Drop | 20% | Drop |
| 335 | 17% | 1% | Drop | 0% | Drop | 18% | Drop |
| 336 | 18% | 1% | 1% | 0% | 0% | 19% | 19% |
| 337 | 18% | 1% | 1% | 0% | 0% | 19% | 19% |
| 338 | 18% | 1% | Drop | 0% | Drop | 19% | Drop |
| 339 | 16% | 1% | Drop | 0% | Drop | 17% | Drop |
| 340 | 20% | 1% | Drop | 0% | Drop | 21% | Drop |
| 341 | 21% | 1% | Drop | 0% | Drop | 22% | Drop |
| 342 | 22% | 1% | Drop | 0% | Drop | 23% | Drop |
| 343 | 17% | 1% | 1% | 0% | 0% | 18% | 18% |
| 344 | 17% | 2% | Drop | 0% | Drop | 19% | Drop |
| 345 | 23% | 1% | Drop | 0% | Drop | 24% | Drop |
| 346 | 18% | 2% | Drop | 0% | Drop | 20% | Drop |
| 347 | 17% | 1% | 1% | 0% | 0% | 18% | 18% |
| 348 | 17% | 1% | Drop | 0% | Drop | 18% | Drop |
| 349 | 17% | 1% | 1% | 0% | 0% | 18% | 18% |
| 350 | 17% | 1% | 1% | 0% | 0% | 18% | 18% |
| 351 | 14% | 2% | Drop | 0% | Drop | 16% | Drop |
| 352 | 17% | 2% | Drop | 0% | Drop | 19% | Drop |
| 353 | 17% | 1% | 1% | 0% | 0% | 18% | 18% |
| 354 | 18% | 2% | 2% | 0% | 0% | 20% | 20% |
| 355 | 16% | 2% | Drop | 0% | Drop | 18% | Drop |
| 356 | 17% | 1% | 1% | 0% | 0% | 18% | 18% |

| Unit | Existing Condition DSC Percent | Vegetation Treatments | | Temporary Roads | | Cumulative DSC Percent | |
|---|---|---|---|---|---|---|---|
| 357 | 16% | 1% | 1% | 0% | 0% | 17% | 17% |
| 358 | 18% | 1% | Drop | 0% | Drop | 19% | Drop |
| 359 | 17% | 1% | Drop | 0% | Drop | 18% | Drop |
| 360 | 16% | 2% | 2% | 0% | 0% | 18% | 18% |
| 361 | 12% | 2% | 2% | 0% | 0% | 14% | 14% |
| 362 | 18% | 1% | Drop | 0% | Drop | 19% | Drop |
| 363 | 17% | 1% | 1% | 0% | 0% | 18% | 18% |
| 364 | 8% | 1% | 1% | 0% | 0% | 9% | 9% |
| 365 | 16% | 1% | 1% | 0% | 0% | 17% | 17% |
| 366 | 16% | 1% | 1% | 0% | 0% | 17% | 17% |
| 367 | 15% | 1% | Drop | 0% | Drop | 16% | Drop |

Table 9 display the total acres of detrimental soil conditions expected from the proposed activities. The action alternatives are designed to reduce the amount of detrimental soil conditions by implementing the project design features described in Chapter 2.

**Table 9. Detrimental Soil Conditions by Alternatives**

| Description | Alternative 2 | Alternative 3 |
|---|---|---|
| Acres of DSC from Past Activities | 1,488 | 908 |
| Acres of DSC from Proposed Activities | 403 | 220 |
| Acres of Cumulative DSC | 1,891 | 1,129 |

Restoration efforts would be undertaken in units where DSCs are expected to exceed 20 percent. Restoration activities to improve soil conditions would include ripping heavily used skid trails and landings. The goal would be to reduce soil compaction and meet the direction provided in Region 6 Supplement 2500-98-1. Several studies discuss the effectiveness of ripping as a soil restoration activity. Seedling survival and growth can be improved by 39 percent after tilling of compacted soils (Froehlich et al., 1983).

Subsoiling restores biological processes that are reduced by soil compaction (Dick et al., 1988). In general, tilling or scarifying a compacted soil improves productivity by reducing the resistance of soil to root penetration and providing improved soil drainage and aeration to enhance seedling establishment and tree growth (Bulmer, 1998). These conditions also improve the environment for soil microorganisms. Soil restoration is not the immediate result of ripping, planting or any other activity. The goal of soil restoration is to create favorable conditions for impaired soils to begin the recovery process.

## Duration of Effects

Displacement and erosion, the loss of topsoil, is a long-term and perhaps a permanent loss of soil productivity. However, management practices outline in the Design Criteria would reduce the occurrence of displacement and erosion to within the Region 6 Soil Quality Standards and Guidelines.

Compaction may last from 10 to 70 years (Gonsior, 1983). Monitoring of 40-year old activities within this project area averaged 13 percent DSC, indicating recovery of compacted soils has occurred.

Reductions in organic matter content reverse quickly as vegetation is established. Organic debris accumulates on the surface and roots grow and are decomposed in the soil. These organic materials break down and release nutrients and improve the quality of the soil by improving its structure and reducing compaction and other DSCs. Loss of organic matter is a short-term change lasting about 10 years once vegetation returns to the soil.

Light and moderate severity burned areas have minor effects well within the natural range of variability for wildfire. Areas burned under conditions that produce light or moderate burn severity would vegetate quickly due to viable seeds or roots that could produce more plants and the complement of microorganisms and nutrients remaining on site (Ryan and Noste, 1985).

Changes in soil microorganisms are not permanent. Recovery would occur as soon as organic matter is present in the soil, which could be immediately after the proposed management is carried out.

Soil erosion would be controlled through the use of erosion control measures. In addition, bare soils would naturally recover or be re-vegetated with native seed. Any erosion that occurs would be short-lived, most likely occurring during the time between the soil disturbance and the implementation of erosion control measures.

## SUMMARY OF ENVIRONMENTAL EFFECTS

**Table 10. Summary of Indicators and Measures by Alternative**

| Resource Element | Indicator | Measure | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|---|---|
| Soil Productivity | Detrimental Soil Conditions | Acres of previously harvest areas treated | 0 | 7,595 | 4,531 |
| | | Acres of total detrimental soil conditions | 1,488 | 1,891 | 1,129 |
| | Droughty Soils | Acres of droughty soil types treated | 0 | 2,049 | 1,322 |
| | Sensitive Soils | Acres of sensitive soil types treated | 0 | 8,545 | 5,287 |
| Soil Erosion | Erosion Potential | Tons/year of hillslope erosion modeled from WEPP | 0.33 | 0.33 | 0.33 |
| | | Acres of soils with high erosion potential treated | 0 | 2,441 | 1,364 |
| | | Miles of temporary roads on soils with high erosion potential treated | 0 | 3.9 | 2.5 |
| Slope Stability | Landslide Potential | Acres of slopes with landslide and landslide prone areas treated | 0 | 663 | 357 |
| | | Miles of temporary roads on slopes with landslide and landslide prone areas treated | 0 | 0 | 0 |

## Compliance with LRMP and Other Relevant Laws, Regulations, Policies and plans

The Organic Administration Act of 1897 authorizes the Secretary of Agriculture to establish regulations to govern the occupancy and use of National Forests "…to improve and protect the forest within the boundaries, or for the purposed of securing favorable conditions of water flows, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States." The project would ensure continued water flows and productive lands that ensure a continuous supply of timber through implementation of BMPs and PDCs. The Bankhead-Jones Farm Tenant Act of 1937 authorizes and directs a program of land conservation and land utilization, in order to correct maladjustments in land use, and thus assist in controlling soil erosion, preserving natural resources, mitigating floods, conserving surface and subsurface moisture, protecting the watershed of navigable streams, and protecting the public lands, health, safety, and welfare. The project would comply with The Bankhead-Jones Farm Tenant Act by ensuring we are mitigating soil erosion, preserving natural resources, and conserving surface and subsurface moisture through implementation of BMPs and PDCs. The project, with described mitigations and BMPs in place, would meet the intent and direction of the Multi-Use Sustained Yield Act of 1960. Sustained yield means achieving and maintaining into perpetuity a high-level annual or regular periodic output of renewable resources without impairment of the productivity of the land.

The NFMA requires that Forest Service regulations implementing NFMA specify guidelines to ensure that timber will be harvested from NFS lands only where "soil, slope, or other watershed conditions will not be irreversibly damaged." 16 USC 1604 (g)(3)(E)(i). Region 6 Soil Quality Standards identified as FSM R-6 Supplement 2500-98-1 were set forth to meet the direction of NFMA to manage NFS lands without permanent impairment of land productivity and to maintain or improve soil quality. In addition, NFMA amends section 18 of Knutson-Vandenberg Act (KV). This amendment authorizes the use of KV funds to protect and improve the future productivity of the renewable resources of the National Forests, including soil and water. This project will prioritize KV funds for rehabilitation of non-system historic road templates that are within the project area. The project complies with 36 CFR 219.20, which requires conservation and protection of soil and water resources. Regional guidance is available from the Region 6 FSM for Watershed Protection and Management 2500-98-1. Regional policy states:

"Design new activities that do not exceed detrimental soil conditions on more than 20 percent of an activity area. (This includes the permanent transportation system). In areas where less than 20 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effect of the current activity following project implementation and restoration must not exceed 20 percent. In areas where more than 20 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effects from project implementation and restoration must, at a minimum, not exceed the conditions prior to the planned activity and should move toward a net improvement in soil quality."

National BMPs and design criteria included in this project for alternatives 2 and 3, ensure that proposed activities will meet all relevant laws mentioned above. Forest Plan standards for the Wallowa-Whitman National Forest will be met in this project as seen below in Table 11.

**Table 11. Forest Plan Compliance**

| Forest Plan Standard | Subject Summary | Compliance Achieved By |
|---|---|---|
| WAW (p.4-21) | Give maintenance of soil productivity and stability priority over uses described or implied in all other management direction, standards, or guidelines. | • Soil type identification and evaluation<br>• Field surveys and office evaluations conducted on a representative group of the proposed Activity Areas<br>• Prioritize soil quality and stability over all other management objectives |
| WAW (p.4-21) | Protection of soil productivity. A minimum of 80% of an Activity Area shall not be detrimentally compacted, displaced, or puddled upon completion of activities. | • Emphasize protection over restoration<br>• Soil improvement activities on areas with prior impacts to maintain or improve soil productivity<br>• Provide contract recommendations to limit impact and aerial extent of disturbance from proposed activities |
| WAW (p.4-21) | Special consideration, protection and mitigation for shallow soils. | • Identify and provide PDCs that avoid and protect shallow soils during project implementation |
| WAW (p.4-21) | Maintain adequate ground cover to minimize soil loss from surface erosion and mass wasting. | • Project design features developed to minimize erosion<br>• Project design features developed to maintain the minimum percent effective ground cover after any soil-disturbing activity based on erosion hazard class<br>• Temporary road locations will be evaluated during |

| | | |
|---|---|---|
| | | implementation. In landslide susceptible areas, units will be field validated and follow Blue Mountain PDCs if slopes are unstable. |

## INTENSITY FACTORS FOR SIGNIFICANCE (FONSI) (40 CFR 1508.27(B))

**3. Unique characteristics of the geographic area such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas.**

There are wetlands present in the project area. Wetlands are a sensitive soil type; however, seeps, springs, and wetlands would have the PACFISH buffer designation and special project design criteria described in alternatives 2 and 3 to ensure protection. Therefore, the effects of the proposed actions to these sensitive soil types do not rise to the level of significance for intensity factor three.

**5. The degree to which the possible effects on the human environment highly uncertain or involve unique or unknown risks.**

Any areas with potential for slope instability will be field validated before implementation. If an area is confirmed as having slope instability, the Blue Mountain PDCs and buffer will be applied to avoid any mass movement.

**10. Whether the action threatens a violation of Federal, State, or local law or requirements imposed for the protection of the environment.**

Relevant laws and requirements include the Wallowa-Whitman Forest Plan, Organic Administration Act of 1897, Bankhead-Jones Act of 1937, The Multiple Use-Sustained Yield Act of 1960, 36 CFR 219.20, The National Forest Management Act of 1976, FSM 2500 Watershed and Air Management, and Region 6 Soil Quality Standards. Project design criteria and BMPs would prevent significant effects to the soil resource. For this reason, the proposed action is consistent with the above laws and requirements, and it does not rise to the level of significance for intensity factor ten.

## OTHER AGENCIES AND INDIVIDUALS CONSULTED

Fredricksen, Richard. Washington State Department of Natural Resources, Forest Practices Engineering Geologist

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